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THE MECHANIC'S TEXT-BOOK AND ENGINEER'S PRACTICAL GUIDE:

CONTAINING

A CONCISE TREATISE

ON THE NATURE AND APPLICATION OF MECHANICAL FORCES; ACTION OF GRAVITY; THE ELEMENTS OF MACHINERY; RULES AND TABLES FOR CALCULATING THE WORKING EFFECTS OF MACHINERY; OF THE STRENGTH, RESISTANCE, AND PRESSURE OF MATERIALS; WITH TABLES OF THE WEIGHT AND COHESIVE STRENGTH OF IRON AND OTHER METALS.

COMPILED AND ARRANGED

BY THOMAS KELT,
OF THE "GLOUCESTER CITY MACHINE COMPANY," N. J.

TO WHICH IS ADDED,

VALUABLE HINTS TO THE YOUNG MECHANIC ON THE CHOICE OF A PROFESSION; MISDIRECTION OF INDUSTRY; INTELLECTUAL CULTIVATION, AND THE STUDIES AND MORALS OF THE MECHANIC, ETC., ETC.

BY JOHN FROST, LL. D.

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PRACTICAL GEOMETRY.

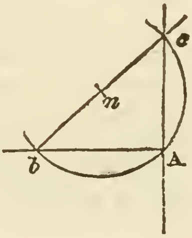
GEOMETRY is the science which investigates and demonstrates the properties of lines on surfaces and solids; hence, PRACTICAL GEOMETRY is the method of applying the rules of the science to practical pur poses.

1. *From any given point, in a straight line, to erect a perpendicular; or, to make a line at right angles with a given line.*

On each side of the point A, from which the line is to be made, take equal distances, as A *b*, A *c*; and from *b* and *c* as centres, with any distance greater than *b* A, or *c* A, describe arcs cutting each other at *d*; then will the line A *d* be the perpendicular required.

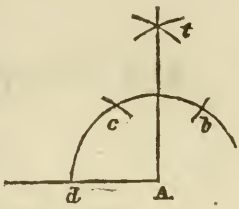
2. *When a perpendicular is to be made at or near the end of a given line.*

With any convenient radius, and with any distance from the given line A *b*, describe a portion of a circle, as *b* A *c*, cutting the given point in A; draw, through the centre of the circle *n*, the line *b n c*; and a line from the point A, cutting the intersections at *c*, is the perpendicular required.



3. *To do the same otherwise.*

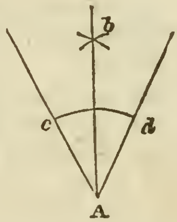
From the given point A, with any convenient radius, describe the arc *d c b ;* from *d*, cut the arc in *c*, and from *c*, cut the arc in *b ;* also, from *c* and *b* as centres, describe arcs cutting each other in *t ;* then will the line A *t* be the perpendicular as required.



Note. — When the three sides of a triangle are in the proportion of 3, 4, and 5 equal parts, respectively, two of the sides form a right angle; and observe that in each of these or the preceding problems, the perpendiculars may be continued below the given lines, if necessarily required.

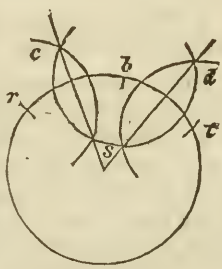
4. *To bisect any given angle.*

From the point A as a centre, with any radius less than the extent of the angle, describe an arc, as *c d;* and from *c* and *d* as centres, describe arcs cutting each other at *b;* then will the line A *b* bisect the angle as required.

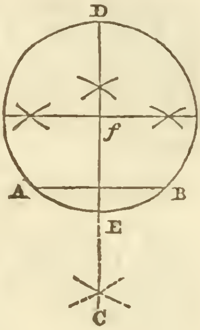


5. *To find the centre of a circle, or radius, that shall cut any three given points, not in a direct line.*

From the middle point *b* as a centre, with any radius, as *b c*, *b d*, describe a portion of a circle, as *c s d;* and from *r* and *t* as centres, with an equal radius, cut the portion of the circle in *c s* and *d s;* draw lines through where the arcs cut each other; and the intersection of the lines at *s* is the centre of the circle as required.

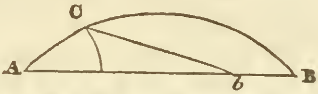


6. *To find the centre of a given circle.*



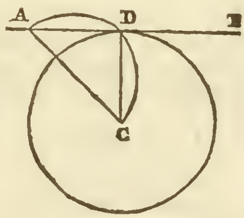
Bisect any chord in the circle, as A B, by a perpendicular, C D; bisect also the diameter E D in *f;* and the intersection of the lines at *f* is the centre of the circle required.

7. *To find the length of any given arc of a circle.*



With the radius A C, equal to $\frac{1}{4}$th the length of the chord of the arc A B, and from A as a centre, cut the arc in *c;* also from B as a centre, with equal radius, cut the chord in *b;* draw the line C *b;* and twice the length of the line is the length of the arc nearly.

8. *Through any given point, to draw a tangent to a circle.*

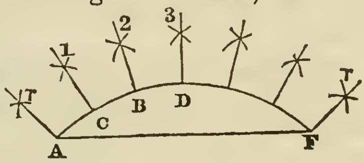


Let the given point be at A; draw the line A C, on which describe the semicircle A D C; draw the line A D B, cutting the circumference in D, which is the tangent as required.

9. *To draw from or to the circumference of a circle lines tending towards the centre, when the centre is inaccessible.*

Divide the whole or any given portion of the circumference into the desired number of equa parts; then, with any radius less than the distance of two

divisions, describe arcs cutting each other, as A 1 B 1, C 2, D 2, &c.; draw the lines C 1, B 2, D 3, &c., which lead to the centre as required.

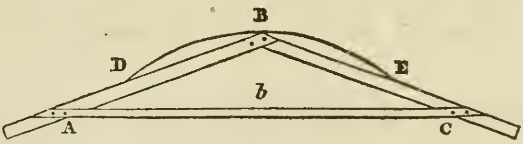


To draw the end lines.

As A r, F r, from C describe the arc r, and with the radius C 1, from A or F as centres, cut the former arcs at r, or r, and the lines A r, F r, will tend to the centre as required.

10. *To describe an arc, or segment of a circle, of large radii.*

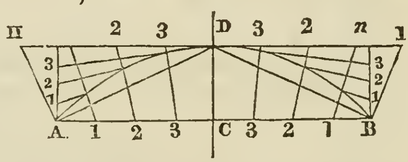
Of any suitable material, construct a triangle, as A B C; make A B, B C, each equal in length to the chord of the arc D E, and height, twice that of the arc



B b. At each end of the chord D E fix a pin, and at B, in the triangle, fix a tracer, (as a pencil,) move the triangle along the pins as guides; and the tracer will describe the arc required.

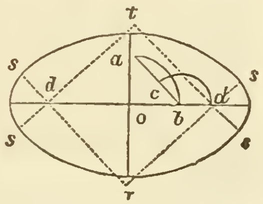
11. *Or otherwise.*

Draw the chord A C B; also draw the line H D I, parallel with the chord, and equal to the height of the segment; bisect the chord in C, and erect the perpendicular C D; join A D, D B; draw A H perpendicular to A D, and B I perpendicular to B D, erect also the perpendiculars A n, B n; divide A B and H I into any



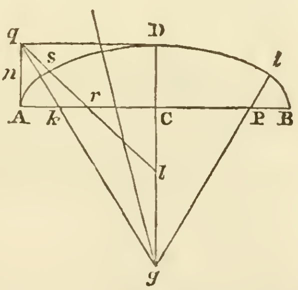
number of equal parts; draw the lines 1 1, 2 2, 3 3, &c.; likewise divide the lines A n, B n, each into half the number of equal parts; draw lines to D from each division in the lines A n, B n, and, through where they intersect the former lines, describe a curve, which will be the arc or segment required.

12. *To describe an ellipse, having the two diameters given.*



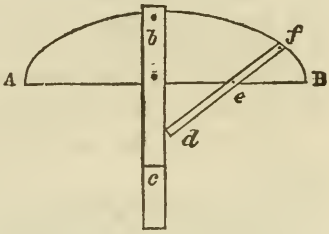
On the intersection of the two diameters as a centre, with a radius equal to the difference of the semi-diameters, describe the arc *a b;* and from *b* as a centre, with half the chord *b c a*, describe the arc *c d;* from *o*, as a centre, with the distance *o d*, cut the diameters in *d r*, *d t;* draw the lines *r*, *s*, *s*, and *t*, *s*, *s;* then from *r* and *t* describe the arcs *s*, *s*, *s*, *s*; also from *d* and *d*, describe the smaller arcs *s*, *s*, *s*, *s*, which will complete the ellipse as required.

13. *To describe an elliptic arch, the width and rise of span being given.*



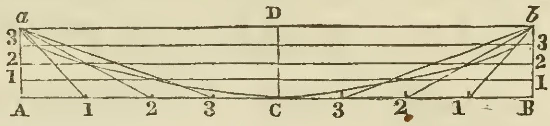
Bisect with a line at right angles the chord or span A B; erect the perpendicular A *q*, and draw the line *q* D equal and parallel to A C; bisect A C and A *q* in *r* and *n:* make C *l* equal to C D, and draw the line *l r q;* draw also the line *n s* D; bisect *s* D with a line at right angles, and meeting the line C D in *g;* draw the line *g q*, make C P equal to C *k*, and draw the line *g* P *i;* then from *g* as a centre, with the radius *g* D, describe the arc *s* D *i;* and from *k* and P as centres, with the radius A *k*, describe the arcs A *s* and B *i*, which completes the arch as required. *Or,*

14. Bisect the chord A B, and fix at right angles any straight guide, as *b c*; prepare, of any suitable material, a rod or staff, equal to half the chord's length, as *d e f*; from the end of the staff, equal to the height of the arch, fix a pin *e*, and at the extremity a tracer *f*; move the staff, keeping its end to the guide and the fixed pin to the chord; and the tracer will describe one half the arc required.



15. *To describe a parabola, the dimensions being given.*

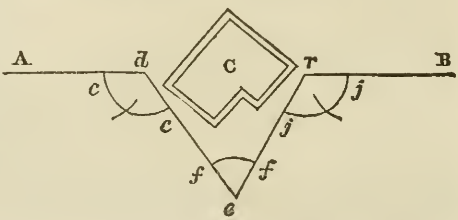
Let A B equal the length, and C D the breadth of the required parabola; divide C A, C B into any num-



ber of equal parts; also divide the perpendiculars A *a* and B *b* into the same number of equal parts; then from *a* and *b* draw lines meeting each division on the line A C B; and a curve line drawn through each intersection will form the parabola required.

16. *To obtain by measurement the length of any direct line, though intercepted by some material object.*

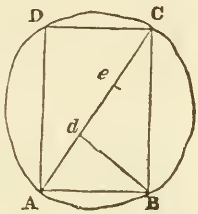
Suppose the distance between A and B is required, but the right line is intercepted by the object C. On the point *d*, with any con-



venient radius, describe the arc *c c*, make the arc twice the radius in length, through which draw the line *d c e*, and on *e* describe another arc equal in length to once the radius, as *e f f;* draw the line *e f r* equal to *e f d;* on *r* describe the arc *j j*, in length twice the radius; continue the line through *r j*, which will be a right line, and *d e*, or *e r*, equal the distance between *d r*, by which the distance between A and B is obtained as required.

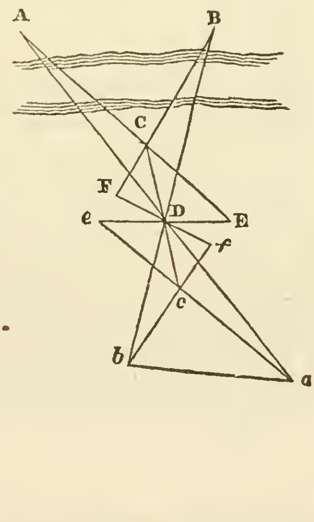
17. *A round piece of timber being given, out of which to cut a beam of strongest section.*

Divide into three equal parts any diameter in the circle, as A *d*, *e* C; from *d* or *e*, erect a perpendicular meeting the circumference of the circle, as *d* B; draw A B and B C, also A D equal to B C, and D C equal to A B, and the rectangle will be a section of the beam as required.



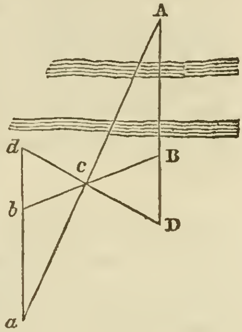
18. *To measure the distance between two objects, both being inaccessible.*

From any point C draw any line C *c*, and bisect it in D; take any point E in the prolongation of A C, and draw the line E *e*, making D *e* equal to D E; in like manner take any point F in the prolongation of B C, and make D *f* equal to F D. Produce A D and *e c* till they meet in *a*, and also B D and *f c* till they meet in *b;* then *a b* equal A B, or the distance between the objects as required.



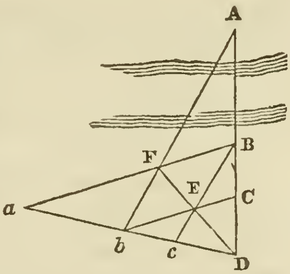
19. *To ascertain the distance, geometrically, of any inaccessible object on an equal plane.*

Let it be required to find the distance between A and B, A being inaccessible; produce the line in the direction of A B to any point, as D; draw the line D *d* at any angle to the line A B; bisect the line D *d*, through which draw the line B *b*, making *c b* equal to B *c*; draw the line *d b a*; also through *c*, in the direction *c* A, draw the line *a c* A, intersecting the line *d b a*; then *b a* equal B A, the distance required.



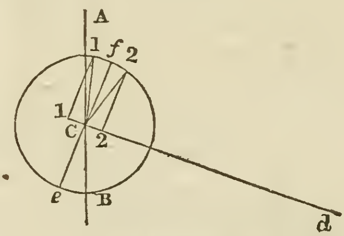
20. *Otherwise.*

Prolong A B to any point D, making B C equal to C D; draw the line D *a* at any angle with D A, and the line C *b* similar to B *c*; draw also the line D E F, which intersects the line D *a*; then *a b* equal B A, or the distance required.



21. *To find the proper position for an eccentric, in relation to the crank in a steam engine, the angle of eccentric rod, and travel of the valve, being given.*

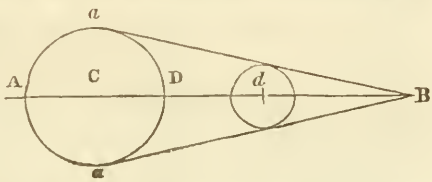
Draw the right line A B, as the situation of the crank at commencement of the stroke; draw also the line C *d*, as the proper given angle of eccentric rod with the crank; then from C as centre, describe a circle equal to the travel of the valve; draw the line *e f* at right angles to the line



C a, draw also the lines 1 1, and 2 2, parallel to the line e f; and at a distance from e f on each side, equal to the lap and lead of the valve, draw the angular lines C 1, C 2, which are the angles of eccentric with the crank, for forward or backward motion, as may be required.

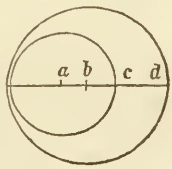
22. *The throw of an eccentric, and the travel of the valve in a steam-engine, also the length of one lever for communicating motion to the valve, being given, to determine the proper length for the other.*

On any right line, as A B, describe a circle A D, equal to the throw of eccentric and travel of valve; then from C as a centre, with a radius equal to the length of lever given, cut the line A B, as at *d*, on which describe a circle, equal to the throw of eccentric or travel of valve, as may be required; draw the tangents B *a*, B *a*, cutting each other in the line A B, and *d* B is the length of the lever as required.



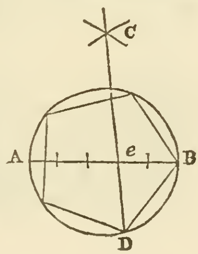
Note. — The throw of an eccentric is equal to the sum of twice the distance between the centres of formation and revolution, as *a b*, or to the degree of eccentricity it is made to describe, as *c d*. And

The travel of a valve is equal the sum of the widths of the two steam openings, and the valve's excess of length more than just sufficient to cover the openings.

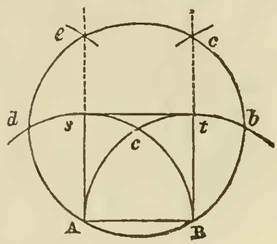


23. *To inscribe any regular polygon in a given circle*

Divide any diameter, as A B, into so many equal parts as the polygon is required to have sides; from A and B as centres, with a radius equal to the diameter, describe arcs cutting each other in C; draw the line C D through the second point of division on the diameter *e*, and the line D B is one side of the polygon required.

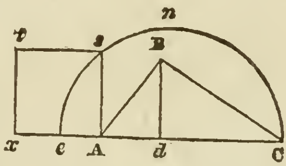


24. *To construct a square upon a given right line.*



From A and B as centres, with the radius A B, describe the arcs A c b, B c d, and from c, with an equal radius, describe the circle or portion of a circle e d, A B, b c; from b d cut the circle at e and c; draw the lines A e, B c, also the line s t, which completes the square as required.

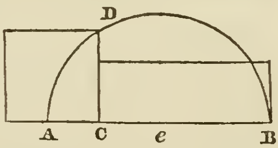
25. *To form a square equal in area to a given triangle.*



Let A B C be the given triangle; let fall the perpendicular B d, and make A e half the height d B; bisect e C, and describe the semicircle e n C; erect the perpendicular A s, or side of the square, then A s t x is the square of equal area as required.

26. *To form a square equal in area to a given rectangle.*

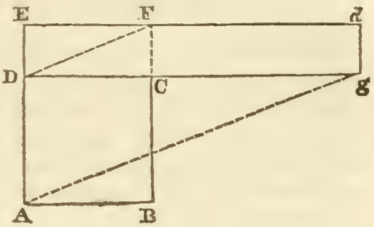
Let the line A B equal the length and breadth of the given rectangle; bisect the line in e, and describe the semicircle A D B; then from A with the breadth, or from B with the length, of the rectangle, cut the line A B at C, and erect the perpendicular C D, meeting the curve at D, and C D equal a side of the square required.



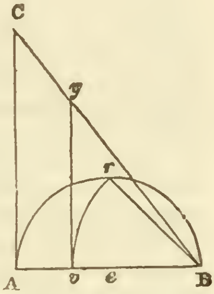
27. *To find the length for a rectangle whose area shall be equal to that of a given square, the breadth of the rectangle being also given.*

Let A B C D be the given square, and D E the given breadth of rectangle; continue the line B C to F, and

draw the line D F; also, continue the line D C to g, and draw the line A g parallel to D F; from the intersection of the lines at g, draw the line g d parallel to D E, and E d parallel to D g; then E D d g is the rectangle as required.



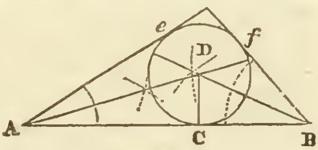
28. *To bisect any given triangle.*



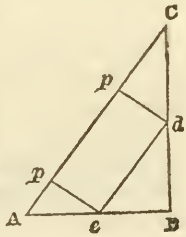
Suppose A B C the given triangle; bisect one of its sides, as A B in *e*, from which describe the semicircle A *r* B; bisect the same in *r*, and from B, with the distance B *r*, cut the diameter A B in *v;* draw the line *v y* parallel to A C, which will bisect the triangle as required.

29. *To describe a circle of greatest diameter in a given triangle.*

Bisect the angles A and B, and draw the intersecting lines A D, B D, cutting each other in D; then from D as centre, with the distance or radii D C, describe the circle C *e f*, as required.



30. *To form a rectangle of greatest surface, in a given triangle.*



Let A B C be the given triangle; bisect any two of its sides, as A B, B C, in *e* and *d;* draw the line *e d;* also at right angles with the line *e d*, draw the lines *e p*, *d p*, and *e p p d* is the rectangle required.

DECIMAL ARITHMETIC

Decimal Arithmetic is the most simple and explicit mode of performing practical calculations, on account of its doing away with the necessity of fractional parts in the fractional form, thereby reducing long and tedious operations to a few figures arranged and worked in all respects according to the usual rules of common arithmetic.

Decimals simply signify tenths; thus, the decimal of a foot is the tenth part of a foot, the decimal of that tenth is the hundredth of a foot, the decimal of that hundredth is the thousandth of a foot, and so might the divisions be carried on and lessened to infinity; but in practice it is seldom necessary to take into account any degree of less measure than a one-hundredth part of the integer or whole number. And, as the entire system consists in supposing the whole number divided into tenths, hundredths, thousandths, &c., no peculiarity of notation is required, otherwise than placing a mark or dot, to distinguish between the whole and any part of the whole; thus, 34·25 gallons signify 34 gallons 2 tenths and 5 hundredths of a gallon; 11·04 yards signify 11 yards and 4 hundredths of a yard, 16·008 shillings signify 16 shillings and 8 thousandth parts of a shilling; from which it must appear plain, that ciphers on the right hand of decimals are of no value whatever; but placed on the left hand, they diminish the decimal value in a tenfold proportion, — for ·6 signify 6 tenths; ·06 signify 6 hundredths; and ·006 signify 6 thousandths of the integer, or whole number.

REDUCTION.

Reduction means the construing or changing of vulgar fractions to decimals of equal value; also finding the fractional value of any decimal given.

Rule 1. Add to the numerator of the fraction any number of ciphers at pleasure, divide the sum by the denominator, and the quotient is the decimal of equivalent value.

Rule 2. Multiply the given decimal by the various fractional denominations of the integer, or whole number, cutting off from the right hand of each product, for decimals, a number of figures equal to the given number of decimals, and thus proceed until the lowest degree, or required value, is obtained.

Ex. 1. Required the decimal equivalent, or decimal of equal value, to $\frac{3}{12}$ of a foot.

$\frac{3 \cdot 00}{12} = \cdot 25$, the decimal required.

Ex. 2. Reduce the fraction $\frac{1}{8}$ of an inch to a decimal of equal value.

$\frac{1 \cdot 000}{8} = \cdot 125$, the decimal required.

Ex. 3. What is the decimal equivalent to $\frac{7}{8}$ of a gallon?

$\frac{7 \cdot 000}{8} = \cdot 875$, the decimal equivalent.

Ex. 4. Required the fractional value of the decimal 40625 of an inch.

$$
\begin{array}{lr}
 & \cdot 40625 \\
\text{Multiply by } \frac{1}{8} & 8 \\
\hline
 & 3 \cdot 25000 \\
\times \frac{2}{16} = \frac{1}{8} & 2 \\
\hline
 & \cdot 50000 \\
\times \frac{2}{32} = \frac{1}{16} & 2 \\
\hline
 & 1 \cdot 00000 \\
\hline\hline
\end{array}
$$

$\frac{3}{8}$ and $\frac{1}{32}$ of an inch, the value required.

Ex. 5. What is the fractional value of ·625 of a cwt.?

$$
\begin{array}{lr}
 & \cdot 625 \\
\text{Multiply by 4 qrs.} & 4 \\
\hline
 & 2 \cdot 500 \\
\times \text{ 28 lbs.} & 28 \\
\hline
 & 14 \cdot 000 \\
\hline\hline
\end{array}
$$

$14 \cdot 000 =$ 2 quarters and 14 lbs., the value required.

Ex. 6. Ascertain the fractional value of ·875 of an imperial gallon.

$$\begin{array}{lr} & \cdot875 \\ \text{Multiply by 4 quarts} & 4 \\ \hline & 3\cdot500 \\ \times \text{ 2 pints} & 2 \\ \hline & 1\cdot000 \end{array}$$

= 3 quarts and 1 pint, the value required.

Ex. 7. What is the fractional value of ·525 of a £. sterling?

$$\begin{array}{lr} & \cdot525 \\ \text{Multiply by 20 sh.} & 20 \\ \hline & 10\cdot500 \\ \times \text{ 12 pence} & 12 \\ \hline & 6\cdot000 \end{array}$$

= 10 shillings and 6 pence, the value required.

Independent of the mark or dot which distinguishes between integers and decimals, the fundamental rules, viz., Addition, Subtraction, Multiplication, and Division, are in all respects the same as in Simple Arithmetic; and an example in each, illustrative of placing the separating point, will no doubt render the whole system sufficiently intelligible, even to the dullest capacity.

Ex. 1. Add into one sum the following integers and decimals.

16·625; 11·4; 20·7831; 12·125; 8·04; and 7·002.

$$\begin{array}{r} 16\cdot625 \\ 11\cdot4 \\ 20\cdot7831 \\ 12\cdot125 \\ 8\cdot04 \\ 7.002 \\ \hline 75\cdot9751 \end{array}$$

= the sum required.

Ex. 2. Subtract 119·80764 from 234·98276

```
  234·98276
  119·80764
  ---------
  115·17512 = the remainder required.
```

Ex. 3. Multiply 62·10372 by 16·732.

```
       62·10372
         16·732
   ------------
       12420744
      18631116
     43472604
    37262232
    6210372
   ------------
   1039·11944304 = the product required.
```

Observe that the number of figures in the product from the right hand, accounted as decimals, are equal to the number of decimals in the multiplier and multiplicand taken together.

Ex. 4. Divide 39·375 by 9·25.

```
9·25 ) 39 375 (4·256 = the quotient required.
       3700
       ----
        2375
        1850
        ----
         5250
         4625
         ----
          6250
          5550
          ----
           700
```

Observe that the number of decimals, in the divisor and quotient together, must be equal to the number in the dividend.

Note. — The operation might be still continued, so as to reduce the quotient to a degree of greater exactitude; but in practice it is quite unnecessary, being even now reduced to a measure of greater nicety than is commonly required.

DEFINITIONS OF ARITHMETICAL SIGNS

EMPLOYED IN THE FOLLOWING CALCULATIONS, WHICH OUGHT TO BE PARTICULARLY ATTENDED TO

$=$	sign of equality,	and signifies	equal to, as 3 added $4=7$.
$+$	"	addition,	"	plus, or more, as $5+3=8$.
$-$	"	subtraction,	"	minus, or less, as $8-3=5$.
$\times$	"	multiplication,	"	multiplied by, as $8\times 3=24$.
$\div$	"	division,	"	divided by, $24\div 4=6$ or $\frac{24}{4}=6$.
$:\,::\,:$	"	proportion,	"	that 2 is to 3 as 4 is to 6, &c.
$\sqrt{}$	"	square root,	"	evolution, or the extr'n of roots;
$\sqrt[3]{}$	"	cube root,	"	thus, $\sqrt{64}=8$ and $\sqrt[3]{64}=4$.
4^2	"	to be squared,	"	involution, or the raising of powers;
4^3	"	to be cubed,	"	thus, $4^2=16$, and $4^3=64$.
$\overline{3+5}\times 4=32$			"	that 3 plus 5 multiplied by $4=32$.
$\sqrt{5^2-3^2}=4$				5 squared, minus 3 squared, the square root of the remainder $=4$.
$\sqrt[3]{\frac{20\times 12}{30}}=2$,				20 multiplied by 12, and divided by 30, the cube root of the quotient $=2$.

DECIMAL APPROXIMATIONS.

FOR FACILITATING CALCULATIONS IN MENSURATION.

Lineal feet multiplied by		·00019	= miles.	
" yards	"	·000568	= "	
Square inches	"	·007	= square feet.	
" yards	"	·0002067	= acres.	
Circular inches	"	·00546	= square feet.	
Cylindrical inches	"	·0004546	= cubic feet.	
" feet	"	·02909	= cubic yards.	
Cubic inches	"	·00058	= cubic feet.	
" feet	"	·03704	= cubic yards.	
" "	"	6·232	= imperial gallons	
" inches	"	·003607	= "	"
Cylindrical feet	"	4·895	= "	"
" inches	"	·002832	= "	"
Cubic inches	"	·263	= lbs. avs.	of cast iron.
" "	"	·281	= "	wrought do.
" "	"	·283	= "	steel.
" "	"	·3225	= "	copper.
" "	"	·3037	= "	brass.
" "	"	·26	= "	zinc.
" "	"	.4103	= "	lead.
" "	"	·2636	= "	tin.
" "	"	·4908	= "	mercury.
Cylindrical inches	"	·2065	= "	cast iron.
"	"	·2168	= "	wrought iron
"	"	·2223	= "	steel.
"	"	·2533	= "	copper.
"	"	·2385	= "	brass.
"	"	·2042	= "	zinc.
"	"	·3223	= "	lead.
"	"	·207	= "	tin.
"	"	·3854	= "	mercury.
Avoirdupois lbs.	"	·009	= cwts.	
"	"	·00045	= tons.	

DECIMAL EQUIVALENTS TO FRACTIONAL PARTS OF LINEAL MEASURES.

One inch, the integer, or whole number.

·96875	are equal to	$\frac{7}{8}$ & $\frac{3}{32}$	·625	are equal to	$\frac{5}{8}$	·28125	are equal to	$\frac{3}{8}$ & $\frac{1}{32}$
·9375		$\frac{7}{8}$ & $\frac{1}{16}$	·59375		$\frac{5}{8}$ & $\frac{3}{32}$	·25		$\frac{1}{4}$
·90625		$\frac{7}{8}$ & $\frac{1}{32}$	·5625		$\frac{5}{8}$ & $\frac{1}{16}$	·21875		$\frac{1}{4}$ & $\frac{3}{32}$
·875		$\frac{7}{8}$	·53125		$\frac{5}{8}$ & $\frac{1}{32}$	·1875		$\frac{1}{4}$ & $\frac{1}{16}$
·84375		$\frac{3}{4}$ & $\frac{3}{32}$	·5		$\frac{1}{2}$	·15625		$\frac{1}{4}$ & $\frac{1}{32}$
·8125		$\frac{3}{4}$ & $\frac{1}{16}$	·46875		$\frac{1}{2}$ & $\frac{3}{32}$	·125		$\frac{1}{8}$
·78125		$\frac{3}{4}$ & $\frac{1}{32}$	·4375		$\frac{1}{2}$ & $\frac{1}{16}$	·09375		$\frac{3}{32}$
·75		$\frac{3}{4}$	·40625		$\frac{1}{2}$ & $\frac{1}{32}$	·0625		$\frac{1}{16}$
·71875		$\frac{5}{8}$ & $\frac{3}{32}$	·375		$\frac{3}{8}$	·03125		$\frac{1}{32}$
·6875		$\frac{5}{8}$ & $\frac{1}{16}$	·34375		$\frac{3}{8}$ & $\frac{1}{32}$			
·65625		$\frac{5}{8}$ & $\frac{1}{32}$	·3125		$\frac{3}{8}$ & $\frac{1}{16}$			

One foot, or 12 inches, the integer.

·9166	are equal to	11 inches.	·4166	are equal to	5 inches.	·0625	are equal to	$\frac{3}{4}$ of inch.
·6333		10 "	·3333		4 "	·0528		$\frac{5}{8}$ "
·75		9 "	·25		3 "	·04166		$\frac{1}{2}$ "
·6666		8 "	·1666		2 "	·03125		$\frac{3}{8}$ "
·5833		7 "	·0833		1 "	·02083		$\frac{1}{4}$ "
·5		6 "	·07291		$\frac{7}{8}$ "	·01041		$\frac{1}{8}$ "

One yard, or 36 inches, the integer.

·9722	are equal to	35 inches.	·6389	are equal to	23 inches.	·3055	are equal to	11 inches.
·9445		34 "	·6111		22 "	·2778		10 "
·9167		33 "	·5833		21 "	·25		9 "
·8889		32 "	·5556		20 "	·2222		8 "
·8611		31 "	·5278		19 "	·1944		7 "
·8333		30 "	·5		18 "	·1666		6 "
·8056		29 "	·4722		17 "	·1389		5 "
·7778		28 "	·4445		16 "	·1111		4 "
·75		27 "	·4166		15 "	·0833		3 "
·7222		26 "	·3889		14 "	·0555		2 "
·6944		25 "	·3611		13 "	·0277		1 "
·6667		24 "	·3333		12 "			

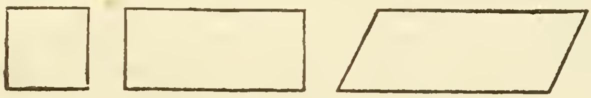
MENSURATION.

Mensuration is that branch of Mathematics which is employed in ascertaining the extension, solidities, and capacities of bodies, capable of being measured.

1. MENSURATION OF SURFACE.

To measure or ascertain the quantity of surface in any right-lined figure whose opposite sides are parallel to each other, as a

Square, Rectangle, Rhomboid,



&c.

Rule. — Multiply the length by the breadth; the product is the area or superficial contents.

Application of the Rule to practical Purposes.

1. The side of a square piece of board is $8\frac{3}{16}$ inches in length; required the area or superficies.

Decimal equivalent to the fraction $\frac{3}{16} = \cdot1875$, (see page 26;) and $8\cdot1875 \times 8\cdot1875 = 67\cdot03515625$ square inches, the area.

2. The length of the fire grate under the boiler of a steam engine is 4 feet 7 inches, and its width 3 feet 6 inches; required the area of the fire grate.

7 in. $= \cdot5833$ and 6 in. $= \cdot5$, (see Table of Equivalents, p. 26;) hence $4\cdot5833 \times 3\cdot5 = 16\cdot04155$ square feet, the area.

3. Required the number of square yards in a floor whose length is $13\frac{1}{2}$, and breadth $9\frac{3}{4}$ feet.

$$13\cdot5 \times 9\cdot75 = 131\cdot625 \div 9 = 14\cdot625 \text{ square yards.}$$

Note 1. — The above rule is rendered equally applicable to figures whose sides are not parallel to each other, by taking

the mean breadth as that by which the contents are to be estimated.

2. The square root of any given sum equals the side of a square of equal area.

3. Any square whose side is equal to the diagonal of another square, contains double the area of that square.

4. Any sum or area, (of which to form a rectangle,) divided by the breadth, the quotient equals the length; or divided by the length, the quotient equals the breadth of the rectangle required.

TRIANGLES.

Any two sides of a right-angled triangle being given, to find the third side.

Rule 1. — Add together the squares of the base and perpendicular, and the square root of the sum is the hypotenuse or longest side.

Rule 2. — Add together the hypotenuse and any one side, multiply the sum by their difference, and the square root of the product equals the other side.

Application to practical Purposes.

1. Wanting to prop a building with raking shores, the top ends of which to be 25 feet from the ground, and the bottom ends 16 feet from the base of the building; what must be their length, independent of any extra length allowed below the surface of the ground?

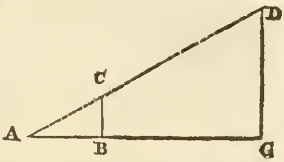
$\overline{25^2 + 16^2} = \sqrt{881} = 29{\cdot}6816$ feet, or $\cdot 6816 \times 12 = 8$ inches; consequently, 29 feet 8 inches nearly.

2. From the top of a wall 18 feet in height, a line was stretched across a canal for the purpose of ascertaining its breadth; the length of the line, when measured, was found to be 40 feet; required the breadth from the opposite embankment to the base of the wall.

$40 - 18 = 22$, and $\overline{40 + 18} \times 22 = \sqrt{1276} = 35{\cdot}72$, or 35 feet 9 inches nearly, the width of the canal.

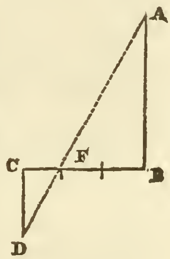
Triangles similar to each other are proportional to each other; hence their utility in ascertaining the heights and distances of inaccessible objects.

Thus, suppose the height of an inaccessible object D is required; I find by means of two staffs, or otherwise, the height of the perpendicular B C and the length of the base line A B; also the distance from A to the base of the object G D;



then A B : B C : : A G : G D. And suppose A B = 6 feet, B C = 2 feet, and A G = 150
6 : 2 : : 150 : 50 feet, the height of D from G.

Again, suppose the inaccessible distance A be required; make the line B A, B C, a right angle, and B C of three or four equal parts of any convenient distance, through one of which, and in a line with the object A, determine the triangle C D F; then the proportion will be as

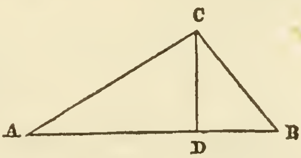


C F : C D : : B F : B A. Let C F = 10 yards, C D = 53, and B F = 30, 10 : 53 : : 30 : 159 yards, the distance from B.

To find the area of a triangle when the base and perpendicular are given.

Rule. — Multiply the base by the perpendicular height, and half the product is the area.

1. The base of the triangle A D B is $11\frac{3}{32}$ inches in length, and the height D C, $3\frac{3}{8}$ inches; required the area.



$\frac{3}{32} = \cdot09375$ and $\frac{3}{8} = \cdot375$, (see page 26 :)

hence $\dfrac{11\cdot09375 \times 3\cdot375}{2} = 18\cdot72075$ square inches, the **area.**

2. The base of a triangle is 53 feet 3 inches, and the perpendicular 7 feet 9 inches; required the area or superficies.

$$\frac{53 \cdot 25 \times 7 \cdot 75}{2} = 206 \cdot 34375 \text{ square feet, the area.}$$

When only the three sides of a triangle can be given to find the area.

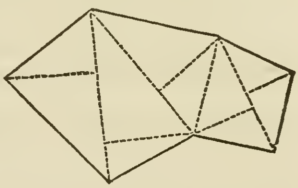
Rule. — From half the sum of the three sides subtract each side severally; multiply the half sum and the three remainders together, and the square root of the product is equal the area required.

Required the area of a triangle, whose three sides are respectively 50, 40, and 30 feet.

$$\frac{50 + 40 + 30}{2} = 60, \text{ or half the sum of the three sides.}$$

$60 - 30 = 30$ first difference,
$60 - 40 = 20$ second difference,
$60 - 50 = 10$ third difference,
then $30 \times 20 \times 10 \times 60 = \sqrt{360000} = 600$, the area required.

Triangles are employed to great advantage in determining the area of any rectilineal figure, as the annexed, and by which the measurement is rendered comparatively simple.



POLYGONS.

Polygons, being composed of triangles, may of course be similarly measured; hence, in regular polygons, multiply the length of a side by the perpendicular height to the centre, and by the number of sides, and half the product is the area.

Table relative to the Construction and Estimation of Polygons.

Name.	No. of sides.	Angle at centre.	Angle at circum.	Perpen. side being 1.	Length of side, radius being 1.	Radius of circle, side being 1.	Radius of circle, per. being 1.	Area, side being 1.
Triangle . .	3	120°	60°	0·2886	1·73	·579	2	0·4330
Square . . .	4	90	90	0·5	1·412	·705	1·41	1
Pentagon .	5	72	108	0·6882	1·174	·852	1·238	1·7204
Hexagon .	6	60	120	0·8660	1	1	1·156	2·5980
Heptagon .	7	$51\frac{3}{7}$	$128\frac{2}{7}$	1·0382	·867	1·16	1·11	3·6339
Octagon . .	8	45	135	1·2071	·765	1·307	1·08	4·8284
Nonagon . .	9	40	140	1·3737	·681	1.47	1·062	6·1818
Decagon . .	10	36	144	1·5388	·616	1·625	1·05	7·6942
Undecagon	11	$32\frac{8}{11}$	$147\frac{3}{11}$	1·7028	·561	1·777	1·04	9·3656
Dodecagon	12	30	150	1·8660	·516	1·94	1·037	11·1961

Application of the Table.

1. The radius of a circle being $6\frac{1}{2}$ feet, required the side of the greatest heptagon that may be inscribed therein.

$$\cdot 867 \times 6\cdot 5 = 5\cdot 6355, \text{ or 5 feet } 7\tfrac{1}{2} \text{ inches nearly.}$$

2. Each side of a pentagon is required to be 9 feet required the radius of circumscribing circle.

$$\cdot 852 \times 9 = 7\cdot 668, \text{ or 7 feet 8 inches.}$$

3. A perpendicular from the centre to either side of an octagon is required to be 12 feet; what must be the radius of circumscribing circle?

$$1\cdot 08 \times 12 = 12\cdot 96, \text{ or 12 feet } 11\tfrac{1}{2} \text{ inches.}$$

4. Each side of a hexagon is $4\frac{1}{2}$ yards; required its superficial contents.

$$4\tfrac{1}{2}^2 \times 2\cdot 598 = 52\cdot 6095 \text{ square yards.}$$

THE CIRCLE AND ITS SECTIONS.

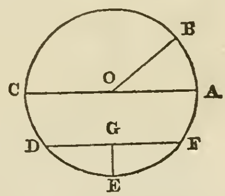
Observations and Definitions.

1. The circle contains a greater area than any other plane figure bounded by the same perimeter or outline.

2. The areas of circles are to each other as the squares of their diameters; any circle twice the diameter of another contains four times the area of the other.

3. The radius of a circle is a straight line drawn from the centre to the circumference, as O B.

4. The diameter of a circle is a straight line drawn through the centre, and terminated both ways at the circumference, as C O A.



5. A chord is a straight line joining any two points of the circumference, as D F.

6. The versed sine is a straight line joining the chord and circumference, as E G.

7. An arc is any part of the circumference, as C D E.

8. A semicircle is half the circumference cut off by a diameter, as C E A.

9. A segment is any portion of a circle cut off by a chord, as D E F.

10. A sector is a part of a circle cut off by two radii, as A O B.

General Rules in Relation to the Circle.

1. Multiply the diameter by 3·1416, the product is the circumference.
2. Multiply the circumference by ·31831, the product is the diameter.
3. Multiply the square of the diameter by ·7854, the product is the area.
4. Multiply the square root of the area by 1·12837, the product is the diameter.
5. Multiply the diameter by ·8862, the product is the side of a square of equal area.
6. Multiply the side of a square by 1·128, the product is the diameter of a circle of equal area.

Application of the Rules as to Purposes of Practice.

1. The diameter of a circle being $7\frac{3}{16}$ inches, required its circumference.

$7{\cdot}1875 \times 3{\cdot}1416 = 22{\cdot}58025$ inches, the circumference.

Or, the diameter being $30\frac{1}{2}$ feet, required the circumference.

$3{\cdot}1416 \times 30{\cdot}5 = 95{\cdot}8188$ feet, the circumference.

2. A straight line, or the circumference of a circle, being 274·89 inches, required the circle's diameter corresponding thereto.

$274{\cdot}89 \times {\cdot}31831 = 87{\cdot}5$ inches diameter.

Or, what is the diameter of a circle, when the circumference is 39 feet?

$31831 \times 39 = 12{\cdot}41409$ feet, and $\cdot 41409 \times 12 = 4{\cdot}96908$ inches, or 12 feet 5 inches, very nearly the diameter.

3. The diameter of a circle is $3\frac{3}{4}$ inches; what is its area in square inches?

$$3{\cdot}75^2 = 14{\cdot}0625 \times {\cdot}7854 = 11{\cdot}044, \text{ \&c., inches area.}$$

Or, suppose the diameter of a circle 25 feet 6 inches, required the area.

$$25{\cdot}5^2 = 650{\cdot}25 \times {\cdot}7854 = 510{\cdot}706, \text{ \&c., feet, the area.}$$

4. What must the diameter of a circle be, to contain an area equal to 706·86 square inches?

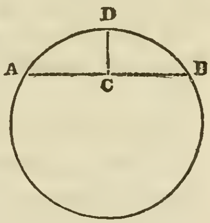
$$\sqrt{706{\cdot}86} = 26{\cdot}586 \times 1{\cdot}12837 = 29{\cdot}998 \text{ or } 30 \text{ inches, the diameter required.}$$

5. The diameter of a circle is $14\frac{1}{4}$ inches; what must I make each side of a square, to be equal in area to the given circle?

$$14{\cdot}25 \times {\cdot}8862 = 12{\cdot}62835 \text{ inches, length of side required.}$$

Any chord and versed sine of a circle being given, to find the diameter.

Rule.—Divide the sum of the squares of the chord and versed sine by the versed sine, the quotient is the diameter of corresponding circle.



1. The chord of a circle A B equal $6\frac{1}{2}$ feet, and the versed sine C D equal 2 feet, required the circle's diameter.

$$\overline{6{\cdot}5^2 + 2^2} = 46{\cdot}25 \div 2 = 23{\cdot}125 \text{ feet, the diameter.}$$

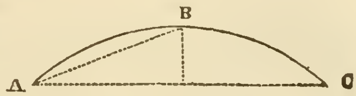
2. In a curve of a railway, I stretched a line 72 feet in length, and the distance from the line to the curve I found to be $1\frac{1}{4}$ ft.; required the radius of the curve.

$$\overline{72^2 + 1{\cdot}25^2} = 5185{\cdot}5625, \text{ and } \frac{5185{\cdot}5625}{1{\cdot}25 \times 2} = 2074{\cdot}225 \text{ ft., the radius.}$$

To find the length of any given arc of a circle.

Rule.—From eight times the chord of half the arc subtract the chord of the whole arc, and one third of the remainder is equal the length of the arc.

Required the length of the arc A B C, the chord A B of half the arc being 4 feet 3 inches, and chord A C of the whole arc 8 feet 4 inches.

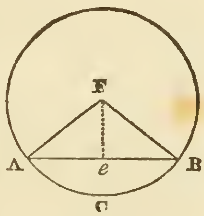


$4\cdot25 \times 8 = 34$, and $34 - 8\cdot333 = \dfrac{25\cdot667}{3} = 8\cdot555$ feet, the length of the arc.

To find the area of the sector of a circle.

Rule.— Multiply the length of the arc by its radius, and half the product is the area.

The length of the arc A C B, equal $9\frac{1}{2}$ feet, and the radii F A, F B, equal each 7 feet, required the area.



$9\cdot5 \times 7 = 65\cdot5 \div 2 = 32\cdot75$, the area.

Note.— The most simple means whereby to find the area of the segment of a circle is, to first find the area of a sector whose arc is equal to that of the given segment; and if it be less than a semicircle, subtract the area of the triangle formed by the chord of the segment and radii of its extremities; but if more than a semicircle, add the area of the triangle to the area of the sector, and the remainder, or sum, is the area of the segment.

Thus, suppose the area of the segment A C B *e* is required, and that the length of the arc A C B equal $9\frac{3}{4}$ feet, F A and F B each equal 7 feet, and the chord A B equal 8 feet 4 inches, also the perpendicular *e* F equal $3\frac{3}{4}$ feet.

$$\frac{9\cdot75 \times 7}{2} = 34\cdot125 \text{ feet, the area of the sector.}$$

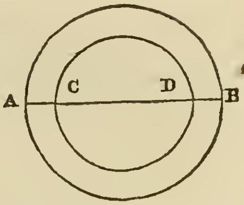
$$\frac{8\cdot333 \times 3\cdot75}{2} = 15\cdot624 \text{ feet, area of the triangle.}$$

And $34\cdot125 - 15\cdot624 = 18\cdot501$ feet, the area of the segment.

To find the area of the space contained between two concentric circles.

Rule.— Multiply the sum of the inside and outside diameters by their difference, and by $\cdot7854$, the product is the area.

1. Suppose the external circle A B equal 32 inches, and internal circle C D equal 28 inches; required the area of the space contained between them.



$\overline{32 + 28} = 60$, and $32 - 28 = 4$, hence $60 \times 4 \times \cdot 7854 = 188 \cdot 496$ in., the area.

2. The exterior diameter of the fly-wheel of a steam engine is 20 feet, and the interior diameter 18½ feet; required the area of the surface or rim of the wheel.

$\overline{20 + 18 \cdot 5} = 38 \cdot 5$ and $20 - 18 \cdot 5 = 1 \cdot 5$, hence $38 \cdot 5 \times 1 \cdot 5 \times \cdot 7854 = 45 \cdot 35$, &c., feet, the area.

To find the area of an ellipsis or oval.

Rule. — Multiply the longest diameter by the shortest, and the product by ·7854; the result is the area.

An oval is 25 inches by 16·5; what are its superficial contents?

$25 \times 16 \cdot 5 = 412 \cdot 5 \times \cdot 7854 = 323 \cdot 9775$ inches, the area.

Note. — Multiply half the sum of the two diameters by 3·1416, and the product is the circumference of the oval or ellipsis.

To find the area of a parabola, or its segment.

Rule. — Multiply the base by the perpendicular height, and two thirds of the product is the area.

What is the area of a parabola whose base is 20 feet and height 12?

$$20 \times 12 = \frac{240 \times 2}{3} = 160 \text{ feet, the area.}$$

Note. — Although the whole of the preceding practical applications or examples are given in measures of feet or inches, these being considered as the most generally familiar, yet the rules are equally applicable to any other unit of measurement whatever, as yards, chains, acres, &c. &c. &c.

2. MENSURATION OF THE SUPERFICIES, SOLIDITIES, AND CAPACITIES OF BODIES.

To find the solidity or capacity of any figure in the cubical form.

Rule.—Multiply the length of any one side by its breadth and by the depth or distance to its opposite side; the product is the solidity or capacity, in equal terms of measurement.

Application of the Rule to practical Purposes.

1. Required the number of cubic inches in a piece of timber $23\frac{1}{2}$ inches long, $7\frac{3}{4}$ inches broad, and $3\frac{5}{8}$ inches in thickness.

$$23{\cdot}5 \times 7{\cdot}75 \times 3{\cdot}625 = 660{\cdot}203 \text{ cubic inches.}$$

2. A rectangular cistern is in length $8\frac{1}{2}$ feet, in breadth $5\frac{1}{4}$ feet, and in depth 4 feet; required its capacity in cubic feet, also its capacity in British imperial gallons.

$8{\cdot}5 \times 5{\cdot}25 \times 4 = 178{\cdot}5$ cubic feet, and $178{\cdot}5 \times 6{\cdot}232$ (see Table of Decimal Approximations, p. 25) $= 1112{\cdot}412$ gallons.

3. A rectangular cistern, capable of containing 520 imperial gallons, is to be $7\frac{1}{4}$ feet in length, and $4\frac{1}{2}$ feet in width; it is required to ascertain the necessary depth.

$7{\cdot}25 \times 4{\cdot}5 \times 6{\cdot}232 = 203{\cdot}318$, and $\frac{520{\cdot}000}{203{\cdot}318} = 2{\cdot}557$ feet, or 2 feet $6\frac{3}{4}$ inches nearly.

4. A rectangular piece of cast iron, 20 inches long and 6 inches broad, is to be formed of sufficient dimensions to weigh 150 lbs.; what will be the depth required?

$20 \times 6 \times {\cdot}263$ (see Table of Decimal Approximations, Cast Iron, p. 25) $= 31{\cdot}96$, and $\frac{150}{31{\cdot}96} = 4{\cdot}69$ in., or 4 and $\frac{11}{16}$ in., the thickness required.

To find the convex surface, and solidity or capacity, of a cylinder.

Rule 1. — Multiply the circumference of the cylinder by its length or height; the product is the convex surface.

Rule 2. — Multiply the area of the diameter by the length or height, and the product is the cylinder's solidity or capacity, as may be required.

Application of the Rules.

1. The circumference of a cylinder is $37\frac{1}{2}$ inches, and its length $54\frac{3}{4}$ inches; required the convex surface in square feet.

$54{\cdot}75 \times 37{\cdot}5 \times {\cdot}007$ (see Table of Approximations) $= 14{\cdot}371$ square feet.

2. A cylindrical piece of timber is 9 inches diameter, and 3 feet 4 inches in length; required its solidity in cubic inches, and also in cubic feet.

3 feet 4 inches $= 40$ inches, and $9^2 \times {\cdot}7854 \times 40 = 2544{\cdot}696$ cubic inches; then $2544{\cdot}696 \times {\cdot}00058 = 1{\cdot}4759$ cubic feet.

. Suppose a well to be 4 feet 9 inches diameter, and $16\frac{1}{2}$ feet from the bottom to the surface of the water: how many imperial gallons are therein contained?

$4{\cdot}75^2 \times 16{\cdot}5 \times 4{\cdot}895 = 1822{\cdot}162$ gallons.

4. Again, suppose the well's diameter the same, and its entire depth 35 feet; required the quantity in cubic yards of material excavated in its formation.

$4{\cdot}75^2 \times 35 \times {\cdot}02909 = 22{\cdot}973$ cubic yards.

5. I have a cylindrical cistern capable of holding 7068 gallons, and its depth is 10 feet; now I want to replace it with one of an equal depth, but capable of holding 12,500 gallons; what must be its diameter?

$4{\cdot}895 \times 10 = 48{\cdot}95$, and $\frac{12500}{48{\cdot}95} = \sqrt{255{\cdot}3} = 15{\cdot}9687$ feet, or 15 feet $11\frac{5}{8}$ inches.

6. A cylindrical piece of lead is required, $7\frac{1}{2}$ inches

diameter, and 168 lbs. in weight; what must be its length in inches?

$$7 \cdot 5^2 \times \cdot 3223 = 18, \text{ and } \frac{168}{18} = 9 \cdot 3 \text{ inches.}$$

To find the length of a cylindrical helix, or spiral, wound round a cylinder.

Rule. — Multiply the circumference of the base by the number of revolutions of the spiral, and to the square of the product add the square of the height; the square root of the sum is the length of the spiral.

Application of the Rule.

1. Required the length of the thread or screw twisting round a cylinder 22 inches in circumference $3\frac{1}{2}$ times, and extending along the axis 16 inches.

$$22 \times 3 \cdot 5 = 77^2 = 5929, \text{ and } 16^2 = 256, \text{ then } \sqrt{5929 + 256} = 78 \cdot 64 \text{ inches.}$$

2. The well of a winding staircase is 5 feet diameter, and height to the top landing 25 feet; the hand-rail is to make $2\frac{1}{2}$ revolutions; required its length.

5 feet diameter = 15·7 feet circumference.

$$15 \cdot 7 \times 2 \cdot 5 = 39 \cdot 25^2 = 1540 \cdot 5625, \text{ and } 25^2 = 625, \text{ then}$$

$$\sqrt{1540 + 625} = 46 \cdot 5 \text{ feet, the length required.}$$

To find the convex surface, solidity, or capacity of a cone or pyramid.

Rule 1. — Multiply the circumference of the base by the slant height, and half the product is the slant surface.

Rule 2. — Multiply the area of the base by the perpendicular height, and one third of the product is the solidity or capacity, as may be required.

Application of the Rules.

1. Required the area, in square inches, of the slant surface of a cone whose slant height equal $18\frac{3}{4}$ inches, and diameter at the base $6\frac{1}{4}$ inches.

$$6 \cdot 25 \times 3 \cdot 1416 = 19 \cdot 635 \text{ circumference of the base; and}$$

$$\frac{19 \cdot 635 \times 18 \cdot 75}{2} = 184 \cdot 078125 \text{ square inches.}$$

2. Required the quantity of lead, in square feet sufficient to cover the slant surface of a hexagonal pyramid whose slant height is 42 feet, and the breadth of each side at the base 4 feet 9 inches.

$$\frac{4{\cdot}75 \times 42 \times 6 \text{ sides}}{2} = 598{\cdot}5 \text{ square feet.}$$

3. What is the solidity of a cone, in cubic inches, the diameter at the base being 15 inches, and perpendicular height 32½ inches?

$$\frac{15^2 \times {\cdot}7854 \times 32{\cdot}5}{3} = 1914{\cdot}4125 \text{ cubic inches.}$$

4. In a square solid pyramid of stone 67 feet in height, and 16½ feet at the base, how many cubic feet?

$$\frac{16{\cdot}5 \times 16{\cdot}5 \times 67}{3} = 6080{\cdot}25 \text{ cubic feet.}$$

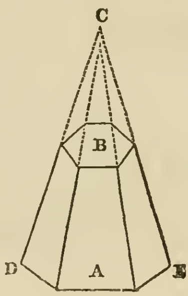
To find the solidity or capacity of any frustum of a cone or pyramid.

Rule. — If the base be a circle, add into one sum the two diameters, or, if a regular polygon, the breadth of one side at the top and at the base; then from the square of the sum subtract the product of these diameters or breadths; multiply the remainder by ·7854, if a circle, or by the tabular area (see Table of Polygons, p. 31) and by one third of the height; and the product is the content in equal terms of unity.

Note. — Where the whole height of the cone or pyramid can be obtained, of which the given frustum forms a part, the most simple method is, first to find the whole contents, then the contents extending beyond the frustum; and, subtracting the less from the greater, leaves the contents of the frustum required.

Application of the Rules.

1. The perpendicular height A B of the frustum of a hexagonal pyramid C D E, is 7½ feet, and the breadth of each side at top and base equal 3¾ and 2½ feet; required the solid contents of the frustum in cubic feet.

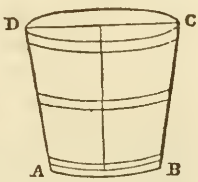


$3{\cdot}75 + 2{\cdot}5 = 6{\cdot}25$, and $6{\cdot}25 \times 6{\cdot}25 = 39{\cdot}0625$, then $3{\cdot}75 \times 2{\cdot}5 = 9{\cdot}375$, and $39{\cdot}0625 - 9{\cdot}375 = 29{\cdot}6875 \times 2{\cdot}598$ (tabular area, p 31) $= 77{\cdot}138 \times 2{\cdot}5$ or $\frac{1}{3}$ of the height $= 192{\cdot}845$ cubic feet.

2. Required the solidity of the frustum of a cone, the top diameter of which is 7 inches, the base diameter $9\frac{1}{2}$, and the perpendicular height 12.

$\overline{7 + 9{\cdot}5}^2 = 272{\cdot}25$, and $7 \times 9{\cdot}5 = 66{\cdot}5$, then $272{\cdot}25 - 66{\cdot}5 = 205{\cdot}75 \times {\cdot}7854 = 161{\cdot}576 \times 4$ or $\frac{1}{3}$ of the height $= 646{\cdot}3$ cubic inches.

3. A vessel in the form of an inverted cone, as A B C D, is 5 feet in diameter at the top, 4 feet at the bottom, and 6 feet in depth; required its capacity in imperial gallons.



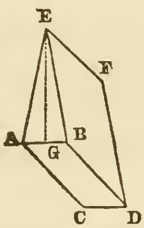
$\overline{5 + 4}^2 = 9^2 = 81$, and $5 \times 4 = 20$, hence $81 - 20 = 61 \times {\cdot}7854$, and by 2 or $\frac{1}{3}$ of the depth $= 95{\cdot}8188$ cubic feet, and $\times\ 6{\cdot}232 = 597{\cdot}1427$ gallons.

To find the solid contents of a wedge.

Rule. — To twice the length of the base add tne length of the edge; multiply the sum by the breadth of the base, and by the perpendicular height from the base, and one sixth of the product is the solid contents.

Application of the Rule.

Required the solidity of a wedge, in cubic inches, the base A B C D being 9 inches by $3\frac{1}{2}$, the edge E F 7 inches, and the perpendicular height G E 15.



$$\frac{\overline{18 + 7} \times 3{\cdot}5 \times 15}{6} = 218{\cdot}75 \text{ cubic inches.}$$

To find the convex surface, the solidity, or the capacity, of a sphere or globe.

Rule 1. — Multiply the square of the diameter by 3·1416; the product is the convex surface.

Rule 2. — Multiply the cube of the diameter by 5236; the product is the solid contents.

Rule 3. — Multiply the cube of the diameter in feet by 3·263, or in inches by ·001888; the product is the capacity in imperial gallons.

Application of the Rules.

1. Required the convex surface, the solidity, and the weight in cast iron of a sphere or ball $10\frac{1}{2}$ inches in diameter.

$10{\cdot}5^2 \times 3{\cdot}1416 = 346{\cdot}3614$ square inches.
$10{\cdot}5^3 \times {\cdot}5236 = 606{\cdot}132$, &c., cubic inches; and
$606{\cdot}132 \times {\cdot}263$ (see Table of Approximations, p. 25) $= 159{\cdot}4$ lbs.

2. A hollow or concave copper ball is required, 8 inches diameter, and in weight just sufficient to sink to its centre in common water; what is the proper thickness of copper of which it must be made?

Weight of a cubic inch of water = ·03617 lbs. } see p. 63.
" " copper = ·3225 "

$$\frac{8^3 \times {\cdot}5236 \times {\cdot}03617}{2} = 4{\cdot}84828 \text{ cub. in. of water to be displaced.}$$

$$\text{And } \frac{4{\cdot}84828}{{\cdot}3225} = 15{\cdot}0334 \text{ cubic inches of copper in the ball.}$$

$$\text{Then } 8^2 \times 3{\cdot}1416 = 201{\cdot}0624, \text{ and } \frac{15{\cdot}0334}{201{\cdot}0624} = {\cdot}0747 \text{ inches, the}$$
thickness of copper required.

${\cdot}0747 \times 16 = \frac{1}{16}$ of an inch full, or 3 lbs. copper to a square foot.

3. What diameter must I make a leaden ball, so as to weigh 72 lbs.?

$$\cdot5236 \times {\cdot}4103 = {\cdot}21483308, \text{ and } \frac{72}{{\cdot}21483308} = \sqrt[3]{340} = 6{\cdot}97$$
inches, diameter.

INSTRUMENTAL ARITHMETIC

OR

UTILITY OF THE SLIDE RULE.

The slide rule is an instrument by which the greater portion of operations in arithmetic and mensuration may be advantageously performed, provided the lines of division and gauge points be made properly correct, and their several values familiarly understood.

The lines of division are distinguished by the letters A B C D; A B and C being each divided alike, and containing what is termed a double radius, or double series of logarithmic numbers, each series being supposed to be divided into 1000 equal parts, and distributed along the radius in the following manner: —

From 1 to	2	contains	301	of those parts, being the log. of		2.
"	3	"	477		"	3.
"	4	"	602		"	4.
"	5	"	699		"	5.
"	6	"	778		"	6.
"	7	"	845		"	7.
"	8	"	903		"	8.
"	9	"	954		"	9

1000 being the whole number.

The line D, on the improved rules, consists of only a single radius; and although of larger radius, the logarithmic series is the same, and disposed of along the line in a similar proportion, forming exactly a line of square roots to the numbers on the lines B C.

NUMERATION.

Numeration teaches us to estimate or properly value the numbers and divisions on the rule in an arithmetical form.

Their values are all entirely governed by the value set upon the first figure, and, being decimally reckoned, advance tenfold from the commencement to the termination of each radius: thus, suppose 1 at the joint be one, the 1 in the middle of the rule is ten, and 1 at the end one hundred: again, suppose 1 at the joint ten, 1 in the middle is 100, and 1 or 10 at the end is 1000, &c., the intermediate divisions on which complete the whole system of its notation.

TO MULTIPLY NUMBERS BY THE RULE.

Set 1 on B opposite to the multiplier on A; and against the number to be multiplied on B is the product on A.

Multiply 6 by 4.

Set 1 on B to 4 on A; and against 6 on B is 24 on A. The slide thus set, against 7 on B is 28 on A.

8	"	32 "
9	"	36 "
10	"	40 "
12	"	48 "
15	"	60 "
25	"	100, &c. &c.

TO DIVIDE NUMBERS UPON THE RULE.

Set the divisor on B to 1 on A; and against the number to be divided on B is the quotient on A.

Divide 63 by 3.

Set 3 on B to 1 on A; and against 63 on B is 21 on A.

PROPORTION, OR RULE OF THREE DIRECT.

Rule. — Set the first term on B to the second on A; and against the third upon B is the fourth upon A.

1. If 4 yards of cloth cost 38 shillings, what will 30 yards cost at the same rate?

Set 4 on B to 38 on A; and against 30 on B is 285 shillings on A.

2. Suppose I pay 31*s.* 6*d.* for 3 cwt. of iron, at what rate is that per ton? 1 *ton* = 20 *cwt.*

Set 3 upon B to 31·5 upon A; and against 20 upon B is 210 upon A.

RULE OF THREE INVERSE.

Rule. — Invert the slide, and the operation is the same as direct proportion.

1. I know that six men are capable of performing a certain given portion of work in eight days, but I want the same performed in three; how many men must there be employed?

Set 6 upon C to 8 upon A; and against 3 upon C is 16 upon A.

2. The lever of a safety valve is 20 inches in length, and 5 inches between the fixed end and centre of the valve; what weight must there be placed on the end of the lever to equipoise a force or pressure of 40 lbs. tending to raise the valve?

Set 5 upon C to 40 upon A; and against 20 on C is 10 on A.

3. If $8\frac{3}{4}$ yards of cloth, $1\frac{1}{2}$ yards in width, be a sufficient quantity, how much will be required of that which is only $\frac{7}{8}$ths in width, to effect the same purpose?

Set 1·5 on C to 8·75 on A; and against ·875 upon C is 15 yards upon A.

SQUARE AND CUBE ROOTS OF NUMBERS.

On the engineer's rule, when the lines C and D are equal at both ends, C is a table of squares, and D a table of roots, as —

Squares,	1	4	9	16	25	36	49	64	81 on C.
Roots,	1	2	3	4	5	6	7	8	9 on D.

To find the geometrical mean proportion between two numbers.

Set one of the numbers upon C to the same number upon D; and against the other number upon C is the mean number or side of an equal square upon D.

Required the mean proportion between 20 and 45.

Set 20 upon C to 20 upon D; and against 45 upon C is 30 on D.

To cube any number, set the number upon C to 1 or 10 upon D; and against the same number upon D is the cube number upon C.

Required the cube of 4.

Set 4 upon C to 1 or 10 upon D; and against 4 upon D is 64 upon C.

To extract the cube root of any number, invert the slide, and set the number upon B to 1 or 10 upon D; and where two numbers of equal value coincide, on the lines B D, is the root of the given number.

Required the cube root of 64.

Set 64 upon B to 1 or 10 upon D; and against 4 upon B is 4 upon D, or root of the given number.

On the common rule, when 1 in the middle of the line C is set opposite to 10 on D, then C is a table of squares, and D a table of roots.

To cube any number by this rule, set the number upon C to 10 upon D; and against the same number upon D is the cube upon C.

MENSURATION OF SURFACE.

1. *Squares, Rectangles, &c.*

Rule.—When the length is given in feet and the breadth in inches, set the breadth on B to 12 on A; and against the length on A is the content in square feet on B.

If the dimensions are all inches, set the breadth on B to 144 upon A; and against the length upon A is the number of square feet on B.

Required the content of a board 15 inches broad and 14 feet long.

Set 15 upon B to 12 upon A; and against 14 upon A is 17·5 square feet on B.

2. *Circles, Polygons, &c.*

Rule.—Set ·7854 upon C to 1 or 10 upon D; then will the lines C and D be a table of areas and diameters.

Areas,	3·14	7·06	12·56	19·63	28·27	38·48	50·26	63·61	upon C.
Diam.,	2	3	4	5	6	7	8	9	upon D

In the common rule, set ·7854 on C to 10 on D; then C is a line or table of areas, and D of diameters, as before.

Set 7 upon B to 22 upon A; then B and A form or become a table of diameters and circumferences of circles.

Cir.,	3·14	6·28	9·42	12·56	15·7	18·85	22	25·13	28·27	upon A.
Dia.,	1	2	3	4	5	6	7	8	9	upon B

Polygons from 3 *to* 12 *sides.*—Set the gauge-poin upon C to 1 or 10 upon D; and against the length o' one side upon D is the area upon C.

Sides,	3	5	6	7	8	9	10	11	12.
Gauge-points,	·433	1·7	2·6	3·63	4·82	6·18	7·69	9·37	11·17

Required the area of an equilateral triangle, each side 12 inches in length.

Set ·433 upon C to 1 upon D; and against 12 upon D are 62·5 square inches upon C.

TABLE OF GAUGE-POINTS FOR THE ENGINEER'S RULE.

Names.		F, F, F.	F, I, I.	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches		578	83	1728	106	1273	105	121
Cubic feet		1	144	1	1833	22	121	33
Imp. gallons		163	231	277	294	353	306	529
Water in lbs.		16	23	276	293	352	305	528
Gold	"	814	1175	141	149	178	155	269
Silver	"	15	216	261	276	334	286	5
Mercury	"	118	169	203	216	258	225	389
Brass	"	193	177	333	354	424	369	637
Copper	"	18	26	319	331	397	345	596
Lead	"	141	203	243	258	31	27	465
Wro't iron	"	207	297	357	338	453	394	682
Cast iron	"	222	32	384	407	489	424	733
Tin	"	219	315	378	401	481	419	728
Steel	"	202	292	352	372	448	385	671
Coal	"	127	183	22	33	28	242	42
Marble	"	591	85	102	116	13	113	195
Freestone	"	632	915	11	1162	14	141	21

FOR THE COMMON SLIDE RULE.

Names.		F, F, F.	F, I, I.	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches		36	518	624	660	799	625	113
Cubic feet		625	9	108	114	138	119	206
Water in lbs.		10	144	174	184	22	191	329
Gold	"	507	735	88	96	118	939	180
Silver	"	938	136	157	173	208	173	354
Mercury	"	738	122	127	132	162	141	242
Brass	"	12	174	207	221	265	23	397
Copper	"	112	163	196	207	247	214	371
Lead	"	880	126	152	162	194	169	289
Wro't Iron	"	129	186	222	235	283	247	423
Cast iron	"	139	2	241	254	304	265	458
Tin	"	137	135	235	25	300	261	454
Steel	"	136	183	22	233	278	239	418
Coal	"	795	114	138	146	176	151	262
Marble	"	370	53	637	725	81	72	121
Freestone	"	394	57	69	728	873	755	132

MENSURATION OF SOLIDITY AND CAPACITY.

General rule. — Set the length upon B to the gauge-point upon A; and against the side of the square, or diameter on D, are the cubic contents, or weight in lbs. on C.

1. Required the cubic contents of a tree 30 feet in length, and 10 inches quarter girt.

Set 20 upon B to 144 (the gauge-point) upon A; and against 10 upon D is 20·75 feet upon C.

2. In a cylinder 9 inches in length and 7 inches diameter, how many cubic inches?

Set 9 upon B to 1273 (the gauge-point) upon A; and against 7 on D is 346 inches on C.

3. What is the weight of a bar of cast iron 3 inches square, and 6 feet long?

Set 6 upon B to 32 (the gauge-point) upon A; and against 3 upon D is 168 lbs. upon C.

By the common rule.

4. Required the weight of a cylinder of wrought iron 10 inches long, and 5½ diameter.

Set 10 upon B to 283 (G. Pt.) upon A; and against 5½ upon D is 66·65 lbs. on C.

5. What is the weight of a dry rope 25 yards long, and 4 inches circumference?

Set 25 upon B to 47 (G. Pt.) upon A; and against 4 on D is 53·16 lbs. on C.

6. What is the weight of a short-linked chain 30 yards in length, and $\frac{6}{16}$ths of an inch in diameter?

Set 30 upon B to 52 (G. Pt.) upon A; and against 6 on D is 29 5 lbs. on C.

LAND SURVEYING.

If the dimensions taken are in chains, the gauge-point is 1 or 10; if in perches, 160; and if in yards, 4840.

Rule. — Set the length upon B to the gauge-point on A; and against the breadth upon A is the content in acres upon B.

1. Required the number of acres or contents of a field 20 chains 50 links in length, and 4 chains 40 links in breadth.

Set 20·5 on B to 1 on A; and against 4·4 on A is 9 acres on B.

2. In a piece of ground 440 yards long, and 44 broad, how many acres?

Set 440 upon B to 4840 on A; and against 44 on A is 4 acres on B.

POWER OF STEAM-ENGINES.

Condensing Engines. — *Rule.* Set 3·5 on C to 10 on D; then D is a line of diameters for cylinders, and C the corresponding number of horses' power; thus,

H. Pr.	$3\frac{1}{2}$	4	5	6	8	10	12	16	20	25	30	40	50	on C.
C.D.	10 in.	$10\frac{3}{4}$	12	$13\frac{1}{4}$	$15\frac{1}{2}$	17	$18\frac{3}{4}$	$21\frac{1}{2}$	24	$26\frac{3}{4}$	$29\frac{1}{2}$	$33\frac{3}{4}$	$37\frac{3}{4}$	on D.

The same is effected on the common rule by setting 5 on C to 12 on D.

Non-condensing Engines. — *Rule.* Set the pressure of steam in lbs. per square inch on B to 4 upon A; and against the cylinder's diameter on D is the number of horses' power upon C.

Required the power of an engine, when the cylinder is 20 inches diameter and steam 30 lbs. per square inch.

Set 30 on B to 4 on A; and against 20 on D is 30 horses' power on C.

The same is effected on the common rule by setting the force of the steam on B to 250 on A.

OF ENGINE BOILERS.

How many superficial feet are contained in a boiler 23 feet in length and $5\frac{1}{2}$ in width?

Set 1 upon B to 23 upon A; and against 5·5 upon B is 126·5 square feet upon A.

If 5 square feet of boiler surface be sufficient for each horse-power, how many horses' power of engine is the boiler equal to?

Set 5 upon B to 126·5 upon A; and against 1 upon B is 25·5 upon A.

STRENGTH OF MATERIALS.

MATERIALS of construction are liable to four different kinds of strain; viz., stretching, crushing, transverse action, and torsion or twisting: the first of which depends upon the body's tenacity alone; the second, on its resistance to compression; the third, on its tenacity and compression combined; and the fourth, on that property by which it opposes any acting force tending to change from a straight line, to that of a spiral direction, the fibres of which the body is composed.

In bodies, the power of tenacity and resistance to compression, in the direction of their length, is as the cross section of their area multiplied by the results of experiments on similar bodies, as exhibited in the following table.

Table showing the Tenacities, Resistances to Compression, and other Properties of the common Materials of Construction.

Names of Bodies.	Absolute		Compared with Cast Iron		
	Tenacity in lbs. per sq. inch.	Resistance to compression in lbs. per sq. in.	Its strength is	Its extensibility is	Its stiffness is
Ash . . .	14130	—	0·23	2·6	0·089
Beech . .	12225	8548	0·15	2·1	0·073
Brass . . .	17968	10304	0·435	0·9	0·49
Brick . . .	275	562	—	—	—
Cast iron . . .	13434	86397	1·000	1·0	1·000
Copper (wrought) .	33000	—	—	—	—
Elm	9720	1033	0·21	2·9	0·073
Fir, or Pine, white .	12346	2028	0·23	2·4	0·1
" " red .	11800	5375	0·3	2·4	0·1
" " yellow .	11835	5445	0·25	2·9	0·087
Granite (Aberdeen)	—	10910	—	—	—
Gun-metal (copper 8, and tin 1) . .	35838	—	0·65	1·25	0·535
Malleable iron . .	56000	—	1·12	0·86	1·3
Larch . . .	12240	5568	0·136	2·3	0·058
Lead . . .	1824	—	0·096	2·5	0·0385
Mahogany, Honduras	11475	8000	0·24	2·9	0·487
Marble . . .	551	6060	—	—	—
Oak	11880	9504	0·25	2·8	0·093
Rope (1 in. in circum.)	200	—	—	—	—
Steel . . .	128000	—	—	—	—
Stone, Bath . .	478	—	—	—	—
" Craigleith .	772	5490	—	—	—
" Dundee . .	2661	6630	—	—	—
" Portland .	857	3729	—	—	—
Tin (cast) . . .	4736	—	0·182	0·75	0·25
Zinc (sheet) . .	9120	—	0·365	0·5	0·75

Comparative Strength and Weight of Ropes and Chains.

Circum. of rope in inches.	Weight per fathom in lbs.	Diameter of chain in inches.	Weight per fathom in lbs.	Proof strength in tons & cwt.		Circum. of rope in inches.	Weight per fathom in lbs.	Diameter of chain in inches.	Weight per fathom in lbs.	Proof strength in tons & cwt.	
$3\frac{1}{2}$	$2\frac{3}{4}$	$\frac{5}{16}$	$5\frac{1}{2}$	1	$5\frac{1}{2}$	10	23	$\frac{7}{8}$	43	10	0
$4\frac{1}{4}$	$4\frac{3}{4}$	$\frac{3}{8}$	8	1	$16\frac{3}{4}$	$10\frac{3}{4}$	28	$\frac{15}{16}$	49	11	11
5	$5\frac{3}{4}$	$\frac{7}{16}$	$10\frac{1}{2}$	2	10	$11\frac{1}{2}$	$30\frac{1}{2}$	1 in.	56	13	8
$5\frac{3}{4}$	7	$\frac{1}{2}$	14	3	$5\frac{1}{2}$	$12\frac{1}{4}$	36	$1\frac{1}{16}$	63	14	18
$6\frac{1}{2}$	$9\frac{3}{4}$	$\frac{9}{16}$	18	4	$3\frac{1}{2}$	13	39	$1\frac{1}{8}$	71	16	14
7	$11\frac{1}{4}$	$\frac{5}{8}$	22	5	2	$13\frac{3}{4}$	45	$1\frac{3}{16}$	79	18	11
8	15	$\frac{11}{16}$	27	6	$4\frac{1}{2}$	$14\frac{1}{2}$	$48\frac{1}{2}$	$1\frac{1}{4}$	87	20	8
$8\frac{3}{4}$	19	$\frac{3}{4}$	32	7	7	$15\frac{1}{4}$	56	$1\frac{5}{16}$	96	22	13
$9\frac{1}{2}$	21	$\frac{13}{16}$	37	8	$13\frac{1}{2}$	16	60	$1\frac{3}{8}$	106	24	18

Note.—It must be understood and also borne in mind that, in estimating the amount of tensile strain to which a body is subjected, the weight of the body itself must also be taken into account; for according to its position so may it approximate to its whole weight, in tending to produce extension within itself; as in the almost constant application of ropes and chains to great depths, considerable heights, &c.

Alloys that are of greater Tenacity than the Sum of their Constituents, as determined by the Experiments of Muschenbroek.

Swedish copper 6 pts., Malacca tin 1;	tenacity per sq.	inch	64,000 lbs.
Chili copper 6 parts, Malacca tin 1;	"	"	60,000 "
Japan copper 5 parts, Banca tin 1;	"	"	57,000 "
Anglesea copper 6 parts, Cornish tin 1;	"	"	41,000 "
Common block-tin 4, lead 1, zinc 1;	"	"	13,000 "
Malacca tin 4, regulus of antimony 1;	"	"	12,000 "
Block tin 3, lead 1;	"	"	10,200 "
Block tin 8, zinc 1;	"	"	10,000 "
Lead 1, zinc 1;	"	"	4,500 "

RESISTANCE TO LATERAL PRESSURE, OR TRANSVERSE ACTION.

The strength of a square or rectangular beam to resist lateral pressure, acting in a perpendicular direction to its length, is as the breadth and square of the depth, and inversely as the length; — thus, a beam twice the breadth of another, all other circumstances being alike, equal twice the strength of the other; or twice the depth, equal four times the strength, and twice the length, equal only half the strength, &c., according to the rule.

Table of Data, containing the Results of Experiments on the Elasticity and Strength of various Species of Timber, by Mr. Barlow.

Species of Timber.	Value of E.	Value of S.	Species of Timber.	Value of E.	Value of S.
Teak	174·7	2462	Elm	50·64	1013
Poona	122·26	2221	Pitch pine . .	88·68	1632
English Oak . .	105	1672	Red pine . . .	133	1341
Canadian do. .	155·5	1766	New England fir	158·5	1102
Dantzic do. .	86·2	1457	Riga fir . . .	90	1100
Adriatic do. .	70·5	1383	Mar Forest do.	63	1200
Ash	119	2026	Larch	76	900
Beech	98	1556	Norway spruce .	105·47	1474

To find the dimensions of a beam capable of sustaining a given weight, with a given degree of deflection, when supported at both ends.

Rule.— Multiply the weight to be supported in lbs. by the cube of the length in feet; divide the product by 32 times the tabular value of E, multiplied into the given deflection in inches; and the quotient is the breadth multiplied by the cube of the depth in inches.

Note 1.— When the beam is intended to be square, then the fourth root of the quotient is the breadth and depth required.

Note 2.— If the beam is to be cylindrical, multiply the quotient by 1·7, and the fourth root of the product is the diameter.

Ex. The distance between the supports of a beam of Riga fir is 16 feet, and the weight it must be capable of sustaining in the middle of its length is 8000 lbs., with a deflection of not more than $\frac{3}{4}$ of an inch; what must be the depth of the beam, supposing the breadth 8 inches?

$$\frac{16 \times 8000}{90 \times 32 \times \cdot 75} = 15175 \div 8 = \sqrt[3]{1897} = 12\cdot 35 \text{ in., the depth}$$

To determine the absolute strength of a rectangular beam of timber, when supported at both ends, and loaded in the middle of its length, as beams in general ought to be calculated to, so that they may be rendered capable of withstanding all accidental cases of emergency.

Rule.— Multiply the tabular value of S by four times the depth of the beam in inches, and by the area of the cross section in inches; divide the product by the distance between the supports in inches, and the quotient will be the absolute strength of the beam in lbs.

Note 1.— If the beam be not laid horizontally, the distance between the supports, for calculation, must be the horizontal distance.

Note 2.—One fourth of the weight obtained by the rule, is the greatest weight that ought to be applied in practice as permanent load.

Note 3.—If the load is to be applied at any other point than the middle, then the strength will be as the product of the two distances is to the square of half the length of the beam between the supports;—or, twice the distance from one end, multiplied by twice from the other, and divided by the whole length, equal the effective length of the beam.

Ex. In a building 18 feet in width, an engine boiler of $5\frac{1}{2}$ tons is to be fixed, the centre of which to be 7 feet from the wall; and having two pieces of red pine, 10 inches by 6, which I can lay across the two walls for the purpose of slinging it at each end,—may I with sufficient confidence apply them, so as to effect this object?

$$\frac{2240 \times 5{\cdot}5}{2} = 6160 \text{ lbs. to carry at each end.}$$

And 18 feet $- 7 = 11$, double each, or 14 and 22, then

$$\frac{14 \times 22}{18} = 17 \text{ feet, or } 204 \text{ inches, effective length of beam.}$$

$$\text{Tabular value of S, red pine, } = \frac{1341 \times 4 \times 10 \times 60}{204} = 15776 \text{ lbs.}$$

the absolute strength of each piece of timber at that point.

To determine the dimensions of a rectangular beam capable of supporting a required weight, with a given degree of deflection, when fixed at one end.

Rule.—Divide the weight to be supported, in lbs., by the tabular value of E, multiplied by the breadth and deflection, both in inches; and the cube root of the quotient, multiplied by the length in feet, equal the depth required in inches.

Ex. A beam of ash is intended to bear a load of 700 lbs. at its extremity; its length being 5 feet, its breadth 4 inches, and the deflection not to exceed $\frac{1}{2}$ of an inch.

$$\text{Tabular value of E} = 119 \times 4 \times {\cdot}5 = 238 \text{ the divisor;}$$

$$\text{then } 700 \div 238 = \sqrt[3]{2{\cdot}94} \times 5 = 7{\cdot}25 \text{ inches, depth of the beam}$$

To find the absolute strength of a rectangular beam, when fixed at one end, and loaded at the other.

Rule. — Multiply the value of S by the depth of the beam, and by the area of its section, both in inches; divide the product by the leverage in inches, and the quotient equal the absolute strength of the beam in lbs.

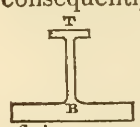
Ex. A beam of Riga fir, 12 inches by $4\frac{1}{2}$, and projecting $6\frac{1}{2}$ feet from the wall; what is the greatest weight it will support at the extremity of its length?

Tabular value of $S = 1100$

$12 \times 4{\cdot}5 = 54$ sectional area,

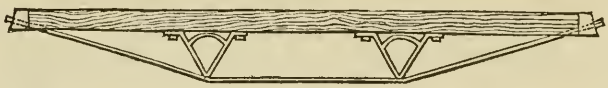
$$\text{Then, } \frac{1100 \times 12 \times 54}{78} = 9138{\cdot}4 \text{ lbs.}$$

When fracture of a beam is produced by vertical pressure, the fibres of the lower section of fracture are separated by extension, whilst at the same time those of the upper portion are destroyed by compression hence exists a point in section where neither the one nor the other takes place, and which is distinguished as the point of neutral axis. Therefore, by the law of fracture thus established, and proper data of tenacity and compression given, as in the table, (p. 52) we are enabled to form metal beams of strongest section with the least possible material. Thus, in cast iron, the resistance to compression is nearly as $6\frac{1}{2}$ to 1 of tenacity; consequently a beam of cast iron, to be of strongest



section, must be of the following form, and a parabola in the direction of its length, the quantity of material in the bottom flange being about $6\frac{1}{2}$ times that of the upper. But such is not the case with beams of timber; for although the tenacity of timber be on an average twice that of its resistance to compression, its flexibility is so great, that any considerable length of beam, where columns cannot be situated to its support,

requires to be strengthened or trussed by iron rods, as in the following manner.



And these applications of principle not only tend to diminish deflection, but the required purpose is also more effectively attained, and that by lighter pieces of timber.

To ascertain the absolute strength of a cast iron beam of the preceding form, or that of strongest section.

Rule.—Multiply the sectional area of the bottom flange in inches by the depth of the beam in inches, and divide the product by the distance between the supports, also in inches; and 514 times the quotient equal the absolute strength of the beam in cwts.

The strongest form in which any given quantity of matter can be disposed is that of a hollow cylinder; and it has been demonstrated that the maximum of strength is obtained in cast iron, when the thickness of the annulus, or ring, amounts to $\frac{1}{5}$th of the cylinder's external diameter; the relative strength of a solid to that of a hollow cylinder being as the diameters of their sections.

A Table showing the Weight or Pressure a Beam of Cast Iron, 1 inch in breadth, will sustain, without destroying its elastic force, when it is supported at each end, and loaded in the middle of its length, and also the deflection in the middle which that weight will produce By Mr. Hodgkinson, Manchester.

Length.	6 feet.		7 feet.		8 feet.		9 feet.		10 feet.	
Depth in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.
3	1278	·24	1089	·33	954	·426	855	·54	765	·66
3½	1739	·205	1482	·28	1298	·365	1164	·46	1041	·57
4	2272	·18	1936	·245	1700	·32	1520	·405	1360	·5
4½	2875	·16	2450	·217	2146	·284	1924	·36	1721	·443
5	3560	·144	3050	·196	2650	·256	2375	·32	2125	·4
6	5112	·12	4356	·163	3816	·213	3420	·27	3060	·33
7	6958	·103	5929	·14	5194	·183	4655	·23	4165	·29
8	9088	·09	7744	·123	6784	·16	6080	·203	5440	·25
9	—	—	9801	·109	8586	·142	7695	·18	6885	·22
10	—	—	12100	·098	10600	·128	9500	·162	8500	·2
11	—	—	—	—	12826	·117	11495	·15	10285	·182
12	—	—	—	—	15264	·107	13680	·135	12240	·17
13	—	—	—	—	—	—	16100	·125	14400	·154
14	—	—	—	—	—	—	18600	·115	16700	·143
	12 feet.		14 feet.		16 feet.		18 feet.		20 feet.	
6	2548	·48	2184	·65	1912	·85	1699	1·08	1530	1·34
7	3471	·41	2975	·58	2603	·73	2314	·93	2082	1·14
8	4532	·36	3884	·49	3396	·64	3020	·81	2720	1·00
9	5733	·32	4914	·44	4302	·57	3825	·72	3438	·89
10	7083	·28	6071	·39	5312	·51	4722	·64	4250	·8
11	8570	·26	7346	·36	6428	·47	5714	·59	5142	·73
12	10192	·24	8736	·33	7648	·43	6796	·54	6120	·67
13	11971	·22	10260	·31	8978	·39	7980	·49	7182	·61
14	13383	·21	11900	·28	10412	·36	9255	·46	8330	·57
15	15937	·19	13360	·26	11952	34	10624	·43	9562	·53
16	18128	·18	15536	·24	13584	·32	12080	·40	10880	·5
17	20500	·17	17500	·23	15353	·3	13647	·38	12282	·47
18	22932	·16	19656	·21	17208	·28	15700	·36	13752	·44

Note.—This Table shows the greatest weight that ever ought to be laid upon a beam for permanent load; and, if there be any liability to jerks, &c., ample allowance must be made also, the weight of the beam itself must be included

To find the weight of a cast iron beam of given dimensions.

Rule. — Multiply the sectional area in inches by the length in feet, and by 3·2, the product equal the weight in lbs.

Ex. Required the weight of a uniform rectangular beam of cast iron, 16 feet in length, 11 inches in breadth, and $1\frac{1}{2}$ inch in thickness.

$$11 \times 1{\cdot}5 \times 16 \times 3{\cdot}2 = 844{\cdot}8 \text{ lbs.}$$

Resistance of Bodies to Flexure by vertical Pressure.

When a piece of timber is employed as a column or support, its tendency to yielding by compression is different according to the proportion between its length and area of its cross section; and supposing the form that of a cylinder whose length is less than seven or eight times its diameter, it is impossible to bend it by any force applied longitudinally, as it will be destroyed by splitting before that bending can take place; but when the length exceeds this, the column will bend under a certain load, and be ultimately destroyed by a similar kind of action to that which has place in the transverse strain.

Columns of cast iron and of other bodies are also similarly circumstanced, this law having recently been fully developed by the experiments of Mr. Hodgkinson on columns of different diameters, and of different lengths.

When the length of a cast iron column with flat ends equals about thirty times its diameter, fracture will be produced wholly by bending of the material. When of less length, fracture takes place partly by crushing and partly by bending. But, when the column is enlarged in the middle of its length from one and a half to twice its diameter at the ends, by being cast hollow, the strength is greater by $\frac{1}{7}$th than in a solid column containing the same quantity of material.

To determine the dimensions of a support or column to bear, without sensible curvature, a given pressure in the direction of its axis.

Rule. — Multiply the pressure to be supported in lbs. by the square of the column's length in feet, and divide the product by twenty times the tabular value of E; and the quotient will be equal to the breadth multiplied by the cube of the least thickness, both being expressed in inches.

Note 1. — When the pillar or support is a square, its side will be the fourth root of the quotient.

2. If the pillar or column be a cylinder, multiply the tabular value of E by 12, and the fourth root of the quotient equal the diameter.

Ex. 1. What should be the least dimensions of an oak support, to bear a weight of 2240 lbs. without sensible flexure, its breadth being 3 inches, and its length 5 feet?

Tabular value of E = 105,

$$\text{and } \frac{2240 \times 5^2}{20 \times 105 \times 3} = \sqrt[3]{8 \cdot 888} = 2 \cdot 05 \text{ inches.}$$

Ex. 2. Required the side of a square piece of Riga fir, 9 feet in length, to bear a permanent weight of 6000 lbs.

Tabular value of E = 96,

$$\text{and } \frac{6000 \times 9^2}{20 \times 96} = \sqrt[4]{253} = 4 \text{ inches nearly.}$$

Dimensions of Cylindrical Columns of Cast Iron to sustain a given load or pressure with safety.

Diameter in inches.	Length or height in feet. 4	6	8	10	12	14	16	18	20	22	24
	Weight or load in cwts.										
2	72	60	49	40	32	26	22	18	15	13	11
2½	119	105	91	77	65	55	47	40	34	29	25
3	178	163	145	128	111	97	84	73	64	56	49
3½	247	232	214	191	172	156	135	119	106	94	83
4	326	310	288	266	242	220	198	178	160	144	130
4½	418	400	379	354	327	301	275	251	229	208	189
5	522	501	479	452	427	394	365	337	310	285	262
6	607	592	573	550	525	497	469	440	413	386	360
7	1032	1013	989	959	924	887	848	808	765	725	686
8	1333	1315	1289	1259	1224	1185	1142	1097	1052	1005	959
9	1716	1697	1672	1640	1603	1561	1515	1467	1416	1364	1311
10	2119	2100	2077	2045	2007	1964	1916	1865	1811	1755	1697
11	2570	2550	2520	2490	2450	2410	2358	2305	2248	2189	2127
12	3050	3040	3020	2970	2930	2900	2830	2780	2730	2670	2600

Practical Utility of the preceding Table.

Ex. Wanting to support the front of a building with cast iron columns 18 feet in length, 8 inches in diameter, and the metal 1 inch in thickness; what weight may I confidently expect each column capable of supporting without tendency to deflection?

Opposite 8 inches diameter and under 18 feet =	1097
Also opposite 6 in. diameter and under 18 feet =	440
=	657 cwt.

Note.—The strength of cast iron as a column being		1·0000
" steel	"	= 2·518
" wrought iron	"	= 1·745
" (oak) Dantzic	"	= ·1088
" red deal	"	= ·0785

Elasticity of Torsion, or Resistance of Bodies to Twisting.

The angle of flexure by torsion is as the length and extensibility of the body directly and inversely as the diameter; hence, the length of a bar or shaft being given, the power, and the leverage the power acts with, being known, and also the number of degrees of torsion that will not affect the action of the machine, to determine the diameter in cast iron with a given angle of flexure.

Rule.—Multiply the power in lbs. by the length of the shaft in feet, and by the leverage in feet; divide the product by fifty-five times the number of degrees in the angle of torsion; and the fourth root of the quotient equal the shaft's diameter in inches.

Ex. Required the diameters for a series of shafts 35 feet in length, and to transmit a power equal to 1245 lbs., acting at the circumference of a wheel 2½ feet

radius, so that the twist of the shafts on the application of the power may not exceed one degree.

$$\frac{1245 \times 35 \times 2{\cdot}5}{55 \times 1} = \sqrt[4]{1981} = 6{\cdot}67 \text{ inches in diameter.}$$

Relative Strength of Metals to resist Torsion.

Cast iron . . .	= 1·	Swedish bar iron .	= 1·05
Copper . . .	= ·48	English do. . .	= 1·12
Yellow Brass .	= ·511	Sheer steel . .	= 1·96
Gun metal . .	= ·55	Cast do. . .	= 2·1

MECHANICS.

PRELIMINARY REMARKS.

MECHANICS, regarded as a science, comprehends the sum of our knowledge relative to the sensible motions of bodies either actually existing or expressed by the opposition of forces tending to produce motion. The science is thus resolvable into a code of discovered laws, applying to the causes which occasion and modify the direction and the velocities of motion, and is therefore distinct from those branches of science in which, although presenting phenomena of motion in sensible portions of matter, we do not consider the circumstances and laws of these motions, but only the effects produced.

When motion itself is considered, the reasoning belongs to mechanics, and it is probable that as our knowledge of the laws which govern the phenomena that are

evolved under the hand of the experimental philosopher becomes more extended, a wider meaning will be given to the science of motion. The definition which is here given of mechanics is not coeval with the name. The science, like most other sciences, has gradually expanded to its present extent. It was originally the science of machines — these being the first subjects of its speculation; and, as every material combination employed for producing or preventing motion may be regarded as a machine, and may be resolved into the same elementary principles as those employed in machines, — the mechanical powers, — the name "mechanics" became to be applied to motion, the tendency to motion of any bodies whatever. Mechanics still continues to be defined by some the *science of force*, and there does not appear to be any valid objection to the definition. Force is the cause of motion, and its laws are identical with the laws of motion; and, consequently, the science of force coincides, in all its parts, with the science of motion, which is mechanics.

ELEMENTS OF MACHINERY.

THE LEVER.

To produce mechanical effects, it is rarely convenient to apply directly our available force, — meaning by mechanical effect moving a body of a certain weight through a certain space, — the assistance of machinery is required. In fact, the essential idea of machinery is, that it renders force available for effecting certain practical ends. Machines prepare, as it were, the raw material of force supplied to us from natural sources. It is transmitted and modified by certain combinations of the elements of machinery, and is given off, at last, in a condition suitable for producing the

desired mechanical effect. We do not create force the end of machinery is just to transmit it and diffuse or concentrate it in one or more points of action. The various diffused or concentrated forces, then, being added together, will just amount to the original available force.

All machinery, when analyzed, will be found to consist of a combination of six simple machines, or elements, commonly called *mechanical powers.* This term is not correctly applied to these elements. They are not powers, or, in other words, sources of power or force; they simply transmit and diffuse or concentrate forces. These six elements are, the *lever*, the *pulley*, the *wheel* and *axle*, the *inclined plane*, the *wedge*, and the *screw.*

To understand, therefore, the nature of any machine, a correct idea of these elements is requisite.

A lever is an inflexible rod, by the application of which one force may balance or overcome another. These forces are termed, respectively, the *power* and the *resistance* or *weight*, not from any difference in the action of the forces, but with reference merely to the intention with which the machine is used; and indeed the same terms are used about all the other mechanical elements. In applying the rod to operate upon any resistance, it must rest upon a centre prop, or fulcrum, somewhere along its length, upon which it turns in the performance of its work. Thus, there are three points in every lever, to be regarded in examining its action, namely, the two points of application of the power and the weight, and the point resting on the fulcrum. There is a certain relation to be observed between the magnitudes of the opposing force, and their distances from the fulcrum, namely, that, in every case, the power, multiplied by its distance from the fulcrum, is equal to the weight, multiplied by its distance from the same point. From this, simple rules may be deduced for calculation.

To know the power to be applied, at a certain distance from the fulcrum, to overcome a resistance acting also at a certain distance, multiply the resistance by its

distance from the fulcrum, which gives its moment, and divide the product by the distance given. Quotient will be the power, it being observed that the distance and the force be each expressed in the same unit of measure. For example, a weight, 1120 lbs., at 3 inches from the fulcrum, is to be balanced by a force at the distance of 10 feet. Now 10 feet are equal to 120 inches; and the moment of 1120 lbs. is $1120 \times 3 = 3360$. Divide this by 120, we have 28 lbs. for the power required.

Again; to know the distance at which a given force ought to be applied to balance a given weight at a certain distance, we must, in like manner, multiply the weight by its distance, as before, and divide by the given power. 1120 lbs., for example, at 3 inches distance, are to be balanced by a force of 28 lbs. To find the distance of this weight, 1120 lbs. multiplied by 3, give 3360, which, divided by 28, give 120 inches, or 10 feet

THE WHEEL AND AXLE, OR CRANE.

The mechanical advantage of the wheel and axle, or crane, is as the velocity of the weight to the velocity of the power; and, being only a modification of the first kind of lever, it of course partakes of the same principles.

To determine the amount of effective power produced from a given power, by means of a crane with known peculiarities.

Rule. — Multiply together the diameter of the circle described by the handle and the number of revolutions of the pinion to one of the wheel; divide the product by the barrel's diameter in equal terms of dimensions; and the quotient is the effective power to 1 of exertive force.

Ex. Let there be a crane, the handle of which describes a circle of 30 inches in diameter; the pinion makes 8 revolutions for 1 of the wheel, and the barrel

is 11 inches in diameter; required the effective power in principle, also the weight that 36 lbs. would raise, friction not taken into account.

$\frac{30 \times 8}{11} = 21{\cdot}9$ to 1 of exertive force, and $21{\cdot}9 \times 36 = 785{\cdot}5$ lbs.

Given any two parts of a crane, to find the third that shall produce any required proportion of mechanical effect.

Rule.—Multiply the two given parts together, and the quotient is the dimensions of the other parts in equal terms of unity.

Ex. Suppose that a crane is required, the ratio of power to effect being as 40 to 1, and that a wheel and pinion 11 to 1 is unavoidably compelled to be employed; also the throw of each handle to be 16 inches; what must be the barrel's diameter, on which the rope or chain must coil?

$16 \times 2 = 32$ inches diameter described by the handle.
And $\frac{32 \times 11}{40} = 8{\cdot}8$ inches, the barrel's diameter.

THE PULLEY.

The principle of the pulley, or more practically the block and tackle, is the distribution of weight on various points of support; the mechanical advantage derived depending entirely upon the flexibility and tension of the rope, and the number of pulleys or sheives in the lower or rising block. Hence, by blocks and tackle of the usual kind, the power is to the weight as the number of cords attached to the lower block; whence the following rules:—

1. Divide the weight to be raised by the number of cords leading to, from, or attached to the lower block; and the quotient is the power required to produce an equilibrium, provided friction did not exist.
2. Divide the weight to be raised by the power to be

applied; the quotient is the number of sheives in, or cords attached to, the rising block.

Ex. Required the power necessary to raise a weight of 3000 lbs. by a four and five sheived block and tackle, the four being the movable or rising block.

Necessarily, there are nine cords leading to and from the rising block; —

$$\text{Consequently, } \frac{3000}{9} = 333 \text{ lbs., the power required.}$$

Ex. 2. I require to raise a weight 4256 lbs.; the amount of my power to effect this object being 500 lbs. What kind of block and tackle must I, of necessity, employ?

$$\frac{4256}{500} = 8{\cdot}51 \text{ cords — of necessity, there must be 4 sheives,}$$

or 9 cords, in the rising block.

As the effective power of the crane may, by additional wheels and pinions, be increased to any required amount, so may the pulley and tackle be similarly augmented by purchase upon purchase. Two of the most useful are known by the term *runner* and *tackle*, and the second by that of *Spanish burton.*

Table showing the Resistance opposed to the Motion of Carriages on different Inclinations of Ascending or Descending Planes, whatever Part of the insistent Weight they are drawn by.

Tens.		Hundreds.								
		100	200	300	400	500	600	700	800	900
		·01	·005	·00333	·0025	·002	·00167	·00143	·00125	·00111
10	·1	·00909	·00476	·00322	·00244	·00196	·00164	·00141	·00123	·0011
20	·05	·00833	·00454	·00312	·00238	·00192	·00161	·00139	·00122	·00109
30	·0333	·00769	·00435	·00303	·00232	·00189	·00159	·00137	·0012	·00107
40	·025	·00714	·00417	·00294	·00227	·00185	·00156	·00135	·00119	·00106
50	·02	·00667	·004	·00286	·00222	·00182	·00154	·00133	·00118	·00105
60	·0166	·00625	·00385	·00278	·00217	·00178	·00151	·00131	·00116	·00104
70	·0143	·00588	·0037	·0027	·00213	·00175	·00149	·0013	·00115	·00103
80	·0125	·00555	·00357	·00263	·00208	·00172	·00147	·00128	·00114	·00102
90	·0111	·00526	·00345	·00256	·00204	·00169	·00145	·00126	·00112	·00101

Note.—Although this table has been calculated particularly for carriages on railway inclines, it may with equal propriety be applied to any other incline, the amount of traction on a level being known.

Application of the preceding Table.

1. What weight will a tractive power of 150 lbs. draw up an incline of 1 in 340, the resistance on the level being estimated at $\frac{1}{240}$th part of the insistent weight?

In a line with 40 in the left-hand column and under 200 is 00417
Also, in the same line and under 300 is . . . . . ·00294

Added together = ·00711

Then $\frac{150}{\cdot 00711} = 21097$ lbs. weight drawn up the plane.

2. What weight would a force of 150 lbs. draw down the same plane, the friction on the level being the same as before?

Friction on the level = ·00417
Gravity of the plane = ·00294 subtract
= ·00123

And $\frac{150}{\cdot 00123} = 121915$ lbs. weight drawn down the plane.

Example of Incline when Velocity is taken into Account.

A power of 230 lbs. at a velocity of 75 feet per minute, is to be employed for moving weights up an inclined plane 12 feet in height and 163 feet in length, the least velocity of the weight to be 8 feet per minute; required the greatest weight that the power is equal to.

$$\frac{230 \times 75 \times 163}{12 \times 8} = \frac{2811750}{96} = 29288 \text{ lbs., or } 13{\cdot}25 \text{ tons.}$$

THE INCLINED PLANE.

The inclined plane is the representative of the second class of mechanical elements. Its fundamental law of action is that of the composition and resolution of forces. The manner in which the advantage is immediately derived from it is, therefore, distinct from that of the first class; there is necessarily a fulcrum, a point round which all the motion takes place, and through which the power acts on the resistance; whereas, in this class, there is no apparent centre of action. The advantage gained by the inclined plane, when the power acts in a parallel direction to the plane, is as the length to the height or angle of inclination. Hence the rule. Divide the weight by the ratio of inclination, and the quotient equal the power that will just support that weight upon the plane. Or, multiply the weight by the height of the plane, and divide by the length — the quotient is the power.

Ex. Required the power or equivalent weight capable of supporting a load of 350 lbs. upon a plane of 1 in 12, or 3 feet in height and 36 feet in length.

$$\frac{350}{12} = 29{\cdot}16 \text{ lbs., or } \frac{350 \times 3}{36} = 29{\cdot}16 \text{ lbs. power, as before}$$

THE WEDGE.

The wedge is a double inclined plane; consequently, its principles are the same. Hence, when two bodies are forced asunder by means of the wedge, in a direction parallel to its head, multiply the resisting power by half the thickness of the head or back of the wedge, and divide the product by the length of one of its inclined sides; the quotient is the force equal to the resistance.

Ex. The breadth of the back or head of a wedge being 3 inches, its inclined sides each 10 inches, re

quired the power necessary to act upon the wedge so as to separate two substances whose resisting force is equal to 150 lbs

$$\frac{150 \times 1{\cdot}5}{10} = 22{\cdot}5 \text{ lbs.}$$

Note. — When only one of the bodies is movable, the whole breadth of the wedge is taken for the multiplier.

THE SCREW.

The screw is another modification of the inclined plane, and it may be said to remove the same kind of practical inconveniences incidental to the use of the latter, that the pulley does in reference to the simple lever. The lever is very limited in the extent of its action; so is the inclined plane. But the pulley multiplies the extent of the action of the lever, by presenting, in effect, a series of levers acting in regular succession; and just such a purpose is effected by the screw. It multiplies the extent of the action of the inclined plane, by presenting, in effect, a continued series of planes.

The screw, in principle, is that of an inclined plane wound round a cylinder, which generates a spiral of uniform inclination, each revolution producing a rise or traverse motion equal to the pitch of the screw, or distance between the two consecutive threads, — the pitch being the height or angle of inclination and the circumference the length of the plane. Hence, the mechanical advantage is, as the circumference of the circle described by the lever where the power acts is to the pitch of the screw, so is the force to the resistance in principle.

Ex. Required the effective power obtained by a screw of $\frac{7}{8}$ inch pitch, and moved by a force equal to 50 lbs. at the extremity of a lever 30 inches in length.

$$\frac{30 \times 2 \times 3{\cdot}1416 \times 50}{875} = 10760 \text{ lbs.}$$

Ex. 2. Required the power necessary to overcome a resistance equal to 7000 lbs. by a screw of $1\frac{1}{4}$ inch pitch and moved by a lever 25 inches in length.

$$\frac{7000 \times 1{\cdot}25}{25 \times 2 \times 3{\cdot}1416} = 55{\cdot}73 \text{ lbs. power.}$$

In the case of a screw acting on the periphery of a toothed wheel, the power is to the resistance as the product of the circle's circumference described by the winch or lever, and radius of the wheel, to the product of the screw's pitch and radius of the axle or point whence the power is transmitted; but observe that, if the screw consist of more than one thread, the apparent pitch must be increased so many times as there are threads in the screw. Hence, to find what weight a given power will equipoise,

Rule. — Multiply together the radius of the wheel the length of the lever at which the power acts, the magnitude of the power, and the constant number 6·2832; divide the product by the radius of the axle into the pitch of the screw, and the quotient is the weight that the power is equal to.

Ex. What weight will be sustained *in equilibrio* by a power of 100 lbs. acting at the end of a lever 24 inches in length, the radius of the axle, or point whence the power is transmitted being 8 inches, the radius of the wheel 14 inches, the screw consisting of a double thread, and the apparent pitch equal $\frac{5}{8}$ of an inch.

$$\frac{14 \times 24 \times 100 \times 6{\cdot}2832}{{\cdot}625 \times 2 \times 8} = 21111{\cdot}55 \text{ lbs., the power sustained.}$$

Note. — It is estimated that about one third more power must be added, to overcome the friction of the screw when loaded, than is necessary to constitute a balance between power and weight.

OF CONTINUOUS CIRCULAR MOTION.

In mechanics, circular motion is transmitted by means of wheels, drums, or pulleys; and accordingly as the driving and driven are of equal or unequal diameters, so are equal or unequal velocities produced. Hence the principle on which the following rules are founded.

1. *When Time is not taken into Account.*

Rule.—Divide the greater diameter, or number of teeth, by the lesser diameter or number of teeth; and the quotient is the number of revolutions the lesser will make, for one of the greater.

Ex. How many revolutions will a pinion of 20 teeth make, for 1 of a wheel with 125?

$$125 \div 20 = 6\cdot25 \text{ or } 6\tfrac{1}{4} \text{ revolutions.}$$

To find the number of revolutions of the last, to one of the first, in a train of wheels and pinions.

Rule.—Divide the product of all the teeth in the driving by the product of all the teeth in the driven; and the quotient equal the ratio of velocity required.

Ex. 1. Required the ratio of velocity of the last, to 1 of the first, in the following train of wheels and pinions; viz., pinions driving,—the first of which contains 10 teeth, the second 15, and third 18. Wheels driven first, 15 teeth, second, 25, and third, 32.

$$\frac{10 \times 15 \times 18}{15 \times 25 \times 32} = \cdot225 \text{ of a revolution the wheel will make to one of the pinion.}$$

Ex. 2. A wheel of 42 teeth giving motion to one of 12, on which shaft is a pulley of 21 inches diameter

driving one of 6; required the number of revolutions of the last pulley to one of the first wheel.

$$\frac{42 \times 21}{12 \times 6} = 12{\cdot}25 \text{ or } 12\tfrac{1}{4} \text{ revolutions.}$$

2. *When Time must be regarded.*

Rule. — Multiply the diameter or number of teeth in the driver, by its velocity in any given time, and divide the product by the required velocity of the driven; the quotient equal the number of teeth or diameter of the driven, to produce the velocity required.

Ex. 1. If a wheel, containing 84 teeth, makes 20 revolutions per minute, how many must another contain, to work in contact, and make 60 revolutions in the same time?

$$\frac{84 \times 20}{60} = 28 \text{ teeth.}$$

Ex. 2. From a shaft making 45 revolutions per minute, and with a pinion 9 inches diameter at the pitch line, I wish to transmit motion at 15 revolutions per minute; what, at the pitch line, must be the diameter of the wheel.

$$\frac{45 \times 9}{15} = 27 \text{ inches.}$$

Ex. 3. Required the diameter of a pulley to make 16 revolutions in the same time as one of 24 inches making 36.

$$\frac{24 \times 36}{16} = 54 \text{ inches.}$$

The distance between the centres and velocities of two wheels being given, to find their proper diameters.

Rule. — Divide the greatest velocity by the least; the quotient is the ratio of diameter the wheels must bear to each other.

Hence, divide the distance between the centres by the ratio $+ 1$; the quotient equal the radius of the smaller wheel; and subtract the radius thus obtained from the distance between the centres; the remainder equal the radius of the other.

Ex. 1. The distance of two shafts from centre to centre is 50 inches, and the velocity of the one 25 revolutions per minute, the other is to make 80 in the same time; the proper diameters of the wheels at the pitch lines are required.

$80 \div 25 = 3{\cdot}2$, ratio of velocity, and $\frac{50}{3{\cdot}2 + 1} = 11{\cdot}9$, the radius of the smaller wheel; then $50 - 11{\cdot}9 = 38{\cdot}1$, radius of larger; their diameters are $11{\cdot}9 \times 2 = 23{\cdot}8$ and $38{\cdot}1 \times 2 = 76{\cdot}2$ inches.

To obtain or diminish an accumulated velocity by means of wheels, pinions, or wheels, pinions, and pulleys, it is necessary that a proportional ratio of velocity should exist, and which is thus attained: multiply the given and required velocities together; and the square root of the product is the mean or proportionate velocity.

Ex. Let the given velocity of a wheel containing 54 teeth equal 16 revolutions per minute, and the given diameter of an intermediate pulley equal 25 inches, to obtain a velocity of 81 revolutions in a machine; required the number of teeth in the intermediate wheel and diameter of the last pulley.

$\sqrt{81 \times 16} = 36$ mean velocity.

$\frac{54 \times 16}{36} = 24$ teeth and $\frac{25 = 36}{81} = 11{\cdot}1$ inches, diameter of pulley.

To determine the proportion of wheels for screw-cutting by a lathe.

In a lathe properly adapted, screws to any degree of pitch, or number of threads in a given length, may be

cut by means of a leading screw of any given pitch, accompanied with change wheels and pinions; coarse pitches being effected generally by means of one wheel and one pinion with a *carrier*, or *intermediate wheel*, which cause no variation or change of motion to take place. Hence the following

Rule. — Divide the number of threads in a given length of the screw which is to be cut, by the number of threads in the same length of the leading screw attached to the lathe; and the quotient is the ratio that the wheel on the end of the screw must bear to that on the end of the lathe spindle.

Ex. Let it be required to cut a screw with 5 threads in an inch, the leading screw being of ½ inch pitch, or containing 2 threads in an inch; what must be the ratio of wheels applied?

$5 + 2 = 2{\cdot}5$, the ratio they must bear to each other.

Then suppose a pinion of 40 teeth be fixed upon for the spindle, —

$40 \times 2{\cdot}5 = 100$ teeth for the wheel on the end of the screw.

But screws of a greater degree of fineness than about 8 threads in an inch are more conveniently cut by an additional wheel and pinion, because of the proper degree of velocity being more effectively attained; and these, on account of revolving upon a stud, are commonly designated the *stud-wheels*, or *stud-wheel* and *pinion;* but the mode of calculation and ratio of screw are the same as in the preceding rule. Hence, all that is further necessary is to fix upon any 3 wheels at pleasure, as those for the spindle and stud-wheels; then multiply the number of teeth in the spindle-wheel by the ratio of the screw, and by the number of teeth in that wheel or pinion which is in contact with the wheel on the end of the screw; divide the product by the stud-wheel in contact with the spindle-wheel; and the quotient is the number of teeth required in the wheel on the end of the leading screw.

Ex. Suppose a screw is required to be cut containing 25 threads in an inch, the leading screw, as before, having two threads in an inch, and that a wheel of 60 teeth is fixed upon for the end of the spindle, 20 for the pinion in contact with the screw-wheel, and 100 for that in contact with the wheel on the end of the spindle; required the number of teeth in the wheel for the end of the leading screw.

$$25 \div 2 = 12{\cdot}5, \text{ and } \frac{60 \times 12{\cdot}5 \times 20}{100} = 150 \text{ teeth.}$$

Or suppose the spindle and screw-wheels to be those fixed upon, also any one of the stud-wheels, to find the number of teeth in the other.

$$\frac{60 \times 12{\cdot}5}{150 \times 100} = 20 \text{ teeth, or } \frac{60 \times 12{\cdot}5 \times 20}{150} = 100 \text{ teeth.}$$

Table of Change Wheels for Screw-cutting; the leading Screw being of ½ inch pitch, or containing 2 threads in an inch.

Number of threads in inch of screw.	Numb. of teeth in		Number of threads in inch of screw.	Number of teeth in				Number of threads in inch of screw.	Number of teeth in			
	Lathe spindle-wheel.	Leading screw-wheel.		Lathe spindle-wheel.	Wheel in contact with spindle-wheel.	Pinion in contact with screw-wheel.	Leading screw-wheel.		Lathe spindle-wheel.	Wheel in contact with spindle-wheel.	Pinion in contact with screw wheel.	Leading screw-wheel.
1	80	40	8¼	40	55	20	60	19	50	95	20	100
1¼	80	50	8½	90	85	20	90	19½	80	120	20	130
1½	80	60	8¾	60	70	20	75	20	60	100	20	120
1¾	80	70	9½	90	90	20	95	20¼	40	90	20	90
2	80	90	3¾	40	60	20	65	21	80	120	20	140
2¼	80	90	10	60	75	20	80	22	60	110	20	120
2½	30	100	10½	50	70	20	75	22½	80	120	20	150
2¾	80	110	11	60	55	20	120	22¾	80	130	20	140
3	80	120	12	90	90	20	120	23¾	40	95	20	100
3¼	80	130	12¾	60	85	20	90	24	65	120	20	130
3½	80	140	13	90	90	20	130	25	60	100	20	150
3¾	80	150	13½	60	90	20	90	25½	30	85	20	90
4	40	80	13¾	80	100	20	110	26	70	130	20	140
4¼	40	85	14	90	90	20	140	27	40	90	20	120
4½	40	90	14¼	60	90	20	95	27½	40	100	20	110
4¾	40	95	15	90	90	20	150	28	75	140	20	150
5	40	100	16	60	80	20	120	28½	30	90	20	95
5½	40	110	16¼	80	100	20	130	30	70	140	20	150
6	40	120	16½	80	110	20	120	32	30	80	20	120
6½	40	130	17	45	85	20	90	33	40	110	20	120
7	40	140	17½	80	100	20	140	34	30	85	20	120
7½	40	150	18	40	60	20	120	35	60	140	20	150
8	30	120	18¾	80	100	20	150	36	30	90	20	120

Table by which to determine the Number of Teeth, or Pitch of Small Wheels, by what is commonly called the Manchester Principle.

Diametral pitch.	Circular pitch.	Diametral pitch.	Circular pitch.
3	1·047	9	·349
4	·785	10	·314
5	·628	12	·262
6	·524	14	·224
7	·449	16	·196
8	·393	20	·157

Ex. 1. Required the number of teeth that a wheel of 16 inches diameter will contain of a 10 pitch.

$16 \times 10 = 160$ teeth, and the circular pitch $=$ ·314 inch.

Ex. 2. What must be the diameter of a wheel for a 9 pitch of 126 teeth?

$\frac{126}{9} = 14$ inches diameter, circular pitch ·349 inch.

Note.—The pitch is reckoned on the diameter of the wheel instead of the circumference, and designated wheels of 8 pitch, 12 pitch, &c.

Strength of the Teeth of Cast Iron Wheels at a given Velocity.

Pitch of teeth in inches	Thickness of teeth in inches.	Breadth of teeth in inches.	Strength of teeth in horse-power at			
			3 feet per second.	4 feet per second.	6 feet per second.	8 feet per second.
3·99	1·9	7·6	20·57	27·43	41·14	54·85
3·78	1·8	7·2	17·49	23·32	34·98	46·64
3·57	1·7	6·8	14·73	19·65	29·46	39·28
3·36	1·6	6·4	12·28	16·38	24·56	32·74
3·15	1·5	6	10·12	13·50	20·24	26·98
2·94	1·4	5·6	8·22	10·97	16·44	21·92
2·73	1·3	5·2	6·58	8·78	13·16	17·54
2·52	1·2	4·8	5·18	6·91	10·36	13·81
2·31	1·1	4·4	3·99	5·32	7·98	10·64
2·1	1·0	4	3·00	4·00	6·00	8·00
1·89	·9	3·6	2·18	2·91	4·36	5·81
1 68	·8	3·2	1·53	2·04	3·06	3·08
1·47	·7	2·8	1·027	1·37	2·04	2·72
1·26	·6	2·4	·64	·86	1·38	1·84
1·05	·5	2	·375	·50	·75	1·00

PRACTICAL PROPERTIES OF WATER

By analysis it is ascertained, that water is composed of the gases oxygen and hydrogen in a state of chemical union; its distinguishing properties, like that of other liquids, being nearly incompressible gravity, capability of flowing, and constant tendency to press outwards in every direction; also that of being easily changed by the absorption of caloric to an aëriform state of any required density or degree of elastic force: hence the principle of the hydraulic press, the water-wheel, the steam engine, &c

Effects produced by Water in its natural State.

Because of liquids possessing the properties of gravity and capability of flowing freely in every direction, sides of vessels, flood-gates, sluices, &c., sustain a pressure equal to the product of the area multiplied by half the depth of the fluid, and by its gravity in equal terms of unity.

But when a sluice or opening through which a liquid may issue is under any given continued head, the pressure is equal the product of the area multiplied into the height from the centre of the opening to the surface of the fluid.

Ex. 1. Required the pressure of water on the sides of a cistern 18 feet in length, 13 in width and 9 in depth.

The terms of measurement or unity are in feet, 1 cubic foot of water = 62·5 lbs.; hence 18 × 9 × 2 + 13 × 9 × 2 = 558 × 4·5 × 62·5 = 156937·5 lbs. weight of water on bottom = 18 × 13 × 9 × 62·5 = 131625 lbs.

Ex. 2. Required the pressure on a sluice 3 feet square, and its centre 30 feet from the surface of the water

3 × 3 × 30 × 62·5 = 16875 lbs. pressure.

The weight of water or other fluid is as the quantity, but the pressure exerted is as the vertical height. Hence, as fluids press equally in every direction, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the sectional area of the column.

Ex. Let a cubical vessel, whose sides are each 4 square feet, have a tube inserted 1 inch in diameter, and 6 feet in height, and let both vessel and tube be filled with water; required the whole weight of the water therein contained, and also the whole pressure exerted intending to burst the vessel.

Cubic contents of the vessel = 8 feet, and each foot = 62·5 lbs.; then $62{\cdot}5 \times 8 = 500$ area of pipe's section = ·7854 inches, and height 72 inches, also a cubic inch of water = ·03617 lbs.; hence, $\cdot7854 \times 72 \times \cdot03617 = 2$ lbs. $+ 500 = 502$ lbs., total weight of the water.

Again; the whole height of the column = 96 inches; then $\cdot7854 \times 96 \times \cdot03617 = 2{\cdot}33$ lbs., pressure of column on an equal area. 144 square inches = 1 square foot, and $\frac{144 \times 4 \times 6 \text{ sides}}{\cdot7854}$ = 4400·4 times the area of the pipe's diameter in the whole surface; therefore, $4400{\cdot}4 \times 2{\cdot}33 = 10253$ lbs., or total amount of pressure exerted.

To find the velocity of water issuing a circular orifice at any given depth from the surface.

Rule.--Multiply the square root of the height or depth to the centre of the orifice by 8·1; and the product is the velocity of the issuing fluid in feet per second.

Ex. Required the velocity of water issuing through an orifice under a head of 11 feet from the surface.

$\sqrt{11} = 3{\cdot}3166 \times 8{\cdot}1 = 26{\cdot}864$ feet, velocity per second.

In the discharge of water by a rectangular aperture in the side of a reservoir, and extending to the surface, the velocity varies nearly as the square root of the height, and the quantity discharged per second equal ⅔rds of the velocity due to the mean height, allowing for the

contraction of the fluid according to the form of the opening, which renders the coëfficient in this case equal to 5·1; whence the following general rules.

1. When the aperture extends to the surface of the fluid. Multiply the area of the opening in feet by the square root of its depth also in feet, and that product by 5·1; then will ⅔rds of the last product equal the quantity discharged, in cubic feet, per second.

2. When the aperture is under a given head. Multiply the area of the aperture, in feet, by the square root of the depth, also in feet, and by 5·1; the product is the quantity discharged, in cubic feet, per second.

Ex. 1. Required the quantity of water in cubic feet per second, discharged through an opening in the side of a dam or weir, the width or length of the opening being 6½ feet, and depth 9 inches, or ·75 of a foot.

$$\text{Square root of } \cdot75 = \cdot866.$$

$$\text{Then } \frac{6{\cdot}5 \times \cdot75 \times \cdot866 \times 5{\cdot}1 \times 2}{3} = 14{\cdot}3839 \text{ cubic feet.}$$

Ex. 2. What would be the quantity discharged through the above opening, if under a head of water 4 feet in height?

Square root of $4 = 2$, and $2 \times 5{\cdot}1 = 10{\cdot}2$ feet, velocity of the water per second. And $6{\cdot}5 \times \cdot75 \times 2 \times 5{\cdot}1 = 49{\cdot}725$ cubic feet discharged in the same time.

The combined properties of gravity and fluidity which water possesses, renders it so available as a source of motive power; gravity being the property by which the power is produced, and fluidity that by which it is so commodiously qualified to the various modifications in which it is employed.

Water, it is ascertained, is subject to the same laws of gravity as those of solid bodies, and thereby accumulates velocity or effect in an equal ratio when falling through an equal space, or descending from an equal height. Hence, the velocity attained is as the square root of the height of its fall; and it is now quite satis-

factorily decided, that, because of the non-elastic property of water, its greatest is obtained when acting by gravity throughout its whole height, whether it be applied on a water-wheel, turbine, or other machine through which circular motion is to be the immediate result.

In regard to water-wheels, and other machines through which motion is produced by the effort of water, much discrepancy of opinion has, until lately, existed, both as to form and velocity, besides other essential points requisite in gaining a maximum of effect with the least possible strain; but these doubts are now in a great measure removed through experiments by the Franklin Institute in this country, added to those in France by Morin, and the results of a patented machine by Whitelaw and Stirrat, Scotland, combined with pertinent observations and remarks by interested parties in this as well as other countries. Hence have been deduced the following demonstrative conclusions: —

1. That, to gain a maximum of effect by a horizontal water-wheel, the water must be laid upon the wheel on the stream side, and the diameter of the wheel so proportioned to the height of the fall, that the water may may be laid on about $52\frac{3}{4}$ degrees distant from the summit of the wheel, or the height of the fall, being 1 the height or diameter of the wheel equal 1·108.

2. That the periphery of a water-wheel ought to move at a velocity equal to about twice the square root of the fall of the water in feet per second, and the number of buckets equal 2·1 times the wheel's diameter in feet; also, that precautionary means be adopted for the escape of the air out of the buckets, either by making the stream of water a few inches narrower than the wheel, or otherwise.

3. That, because of water producing a less efficient power by impulse than gravity, turbines, or machines through which the motion is obtained by reaction, are greatly preferable to undershot, or low-breast wheels.

4. That a head of water is required sufficient to cause the velocity of its flowing to be as 3 to 2 of the wheel; $\frac{1}{9}$ of the wheel's diameter being an approximate height, near enough for practical purposes.

5. That the effective power of a wheel constructed according to these restrictions, is equal to the product of the number of cubic feet and velocity in feet per minute, multiplied into ·001325.

Example for general Illustration.

Suppose a fall of water 25 feet in height, over which is delivered 112 cubic feet per minute; required the various peculiar requisites for a wheel to be in accordance with the preceding rules.

1st. $25 \times 1{\cdot}08 = 27$ feet, the wheel's diameter.
2d. $\sqrt{25} \times 2 = 10$ feet, velocity of the wheel in feet per second.
Also: $27 \times 2{\cdot}1 = 56{\cdot}7$, say 57 buckets.
3d. $27 \div 9 = 3$ feet, head of water required.
4th. $112 \times 10 \times 60 \times {\cdot}001325 = 89$ horses' power.

The turbine of Fourneyron, in France, and the patented water-mill of Whitelaw and Stirrat, Scotland, have, of late years, attracted a considerable share of public attention; their simplicity of construction and asserted effects in like situations, being equal to those of the best applied water-wheels. In their manner of construction they differ, but in principle they are the same; the action of each being created by a centrifugal and tangential force, caused by the weight or impulsion of a column of water whose height or altitude is equal to twice the height of the fall due to the water's velocity; and in order to produce a maximum of effect in either the one or the other by the pressure and centrifugal force of the effluent water, it is necessary that the emitting tubes or helical channels of the machine be so curved that the apertures shall be in a right line with the radius of the wheel.

1. That turbines are equally adapted to great as to small waterfalls.

2. That they are capable of transmitting a useful effect to from 70 to 78 per cent. of the absolute power.

3. That their velocities may vary considerably from the maximum effect, without differing sensibly from it.

4. That they will work nearly as effectually when drowned to the depth of 6 feet as when free, and, consequently, they will make use of the whole of the fall when placed below the level of extreme low water.

5. That they receive variable quantities of water, without altering the ratio of the power to the effect.

STEAM POWER.

There is no application of science to the arts of more importance, and more extensive in its effects, than that of the employment of steam for driving all kinds of machinery. It is not my intention to enter into the details of the power of steam or the steam-engine, but to give some practical rules, the utility of which have been tested.

Steam is of great utility as a productive source of motive power; in this respect, its properties are, elastic force, expansive force, and reduction by condensation. *Elastic* signifies the whole urgency or power the steam is capable of exerting with undiminished effect. By *expansive force* is generally understood the amount of diminishing effect of the steam on the piston of a steam-engine, reckoning from that point of the stroke where the steam of uniform elastic force is cut off; but it is more properly the force which steam is capable of exerting, when expanded to a known number of times its original bulk. And *condensation*, here understood,

is the abstraction or reduction of heat by another body and consequently not properly a contained property of the steam, but an effect produced by combined agency, in which steam is the principal; because any colder body will extract the heat and produce condensation, but steam cannot be so beneficially replaced by any other fluid capable of maintaining equal results.

The rules formed by experimenters, as corresponding with the results of their experiments on the elastic force of steam at given temperatures, vary, but approximate so closely, that the following rule, because of being simple, may, in practice, be taken in preference to any other.

Rule. — To the temperature of the steam, in degrees of Fahrenheit, add 100; divide the sum by 177; and the 6th power of the quotient equal the force in inches of mercury.

Ex. Required the force of steam corresponding to a temperature of 312°.

$$\frac{312 + 100}{177} = 2{\cdot}3277^6 = 159 \text{ inches of mercury.}$$

To estimate the amount of advantage gained by using steam expansively in a steam-engine.

When steam of a uniform elastic force is employed throughout the whole ascent or descent of the piston, the amount of effect produced is as the quantity of steam expended. But let the steam be shut off at any portion of the stroke, — say, for instance, at one-half, — it expands by degrees until the termination of the stroke, and then exerts half its original force; hence an accumulation of effect in proportion to the quantity of steam.

Rule. — Divide the length of the stroke by the distance or space into which the dense steam is admitted, and find the hyperbolic logarithm of the quotient, to which add 1; and the sum is the ratio of the gain.

Ex. Suppose an engine with a stroke of 6 feet, and the steam cut off when the piston has moved through ; required the ratio of gain by uniform and expansive force.

$6 \div 2 = 3$; hyperbolic logarithm of $3 = 1{\cdot}0986 + 1 = 2{\cdot}0986$, ratio of effect; that is, supposing the whole effect of the steam to be 3, the effect by the steam being cut off at $\frac{1}{3} = 2{\cdot}0986$.

Again; let the greatest elastic force of steam in the cylinder of an engine equal 48 lbs. per square inch, and let it be cut off from entering the cylinder when the piston has moved $4\frac{1}{2}$ inches, the whole stroke being 18; required an equivalent force of the steam throughout the whole stroke.

$18 \div 4{\cdot}5 = 4$, and $48 \div 4 = 12$.
Logarithm of $4 + 1 = 2{\cdot}38629$.
Then $2{\cdot}38629 \times 12 = 28{\cdot}635$ lbs. per square inch.

In regard to the other case of expansion, when the temperature is constant, the bulk is inversely as the pressure; thus, suppose steam at 30 lbs. per square inch, required its bulk to that of original bulk, when expanded so as to retain a pressure equal to that of the atmosphere, or 15 lbs.

$$\frac{15 + 30}{15} = 3 \text{ times its original bulk.}$$

It is because of the latent heat in steam, or water in an aëriform state, that it becomes of such essential service in heating, boiling, drying, &c. In the heating of buildings, its economy, efficiency, and simplicity of application, are alike acknowledged; the steam, being simply conducted through all the departments by pipes, by extent of circulation condenses, — the latent heat being thus given to the pipes, and diffused by radiation. In boiling, its efficiency is considerably increased, if advantage be taken of sufficiently enclosing the fluid, and reducing the pressure on its surface, by means of

an air-pump. Thus. water in a vacuum boils at about a temperature of 98°; and in sugar-refining, where such means are employed, the sirup is boiled at 150°

Effects produced by Water in an Aëriform State.

When water in a vessel is subjected to the action of fire, it readily imbibes the heat, or fluid principle of which the fire is the immediate cause, and, sooner or later, according to the intensity of the heat, attains a temperature of 212° Fahrenheit. If, at this point of temperature, the water be not enclosed, but exposed to atmospheric pressure, ebullition will take place, and steam or vapor will ascend through the water, carrying with it the superabundant heat, or that which the water cannot, under such circumstances of pressure, absorb, to be retained, and to indicate a higher temperature.

Water, in attaining the aëriform state, is thus uniformly confined to the same laws, under every degree of pressure; but, as the pressure is augmented, so is the indicated temperature proportionately elevated. Hence the various densities of steam, and corresponding degrees of elastic force.

Table of the Elastic Force of Steam, and corresponding Temperature of the Water with which it is in Contact.

Pressure per square inch, atmospheric pressure included.		Elastic Force in		Temperature in Degrees of			Volume of Steam compared with Vol. of Water.
lbs.	kilog.	Inches of Mercury.	Metres of Mercury.	Fahr.	Reaum.	Cent.	
14·7	6·668	30·00	·762	212·0	80·0	100·0	1711
15	6·80	30·60	·778	212·8	80·4	100·4	1670
16	7·26	32·64	·829	216·3	81·9	102·4	1573
17	7·71	34·68	·880	219·6	83·3	104·2	1488
18	8·16	36·72	·932	222·7	84·7	105·9	1411
19	8·62	38·76	·984	225·6	86·0	107·6	1343
20	9·07	40·80	1·037	228·5	87·3	109·2	1281
21	9·52	42·84	1·089	231·2	88·5	110·7	1225
22	9·98	44·88	1·140	233·8	89·7	112·1	1174
23	10·43	46·92	1·192	236·3	90·8	113·5	1127
24	10·88	48·96	1·244	238·7	91·9	114·8	1084
25	11·34	51·00	1·296	241·0	93·0	116·1	1044
26	11·79	53.04	1·348	243·3	93·9	117·4	1007
27	12·25	55·08	1 400	215·5	94·9	118·6	973
28	12·70	57·12	1·452	247·6	95·8	119·8	941
29	13·15	59·16	1·503	249·6	96·7	120·9	911
30	13·61	61·21	1·555	251·6	97·6	122·0	883
31	14·06	63·24	1·607	253·6	98·5	123·1	857
32	14·51	65·28	1·659	255·5	99·3	124·2	833
33	14·97	67·32	1·711	257·3	100·1	125·2	810
34	15·42	69·36	1·763	259·1	100·9	126·2	788
35	15·87	71·40	1·814	260·9	101·7	127·2	767
36	16·33	73·44	1·866	262·6	102·5	128·1	748
37	16·78	75·48	1·918	264·3	103·2	129·1	729
38	17·23	77·52	1·970	265·9	104·0	129·9	712
39	17·69	79·56	2·022	267·5	104·7	130·8	695
40	18·14	81·60	2·074	269·1	105·4	131·7	679
41	18·59	83·64	2·126	270·6	106·0	132·6	664
42	19·05	85·68	2·178	272·1	106·7	133·4	649
43	19·50	87·72	2·229	273·6	107·4	134·2	635
44	19·96	89·76	2·281	275·0	108·0	135·0	622
45	20·41	91·80	2·333	276·4	108·6	135·8	610
46	20·86	93·84	2·385	277·8	109·2	136·6	598
47	21·32	95·88	2·437	279·2	109·9	137·3	586
48	21·77	97·92	2·489	280·5	110·4	138·1	575
49	22·22	99·96	2·541	281·9	111·1	138·8	564
50	22·68	102·00	2·592	283·2	111·6	139·6	554

The preceding table is peculiarly adapted for estimating the power of steam engines on the condensing principle, because, in such, the effective force of the steam is the difference between the total force and the resisting vapor retained in the condenser. The following table is more adapted for estimating the effects of non-condensing engines; as, in such, the atmospheric pressure is not generally taken into account, engines of this principle being supposed to work in a medium; or, the atmospheric pressure on the boilers, to cause a greater density of steam, is equal to the resisting atmosphere which the effluent steam has to contend with, on leaving the cylinder.

Steam, independent of the heat indicated by an immersed thermometer, also contains heat that cannot be measured by any instrument at present known, and, in consequence of which, is termed latent or concealed heat; the only positive proof we have of its existence being that of incontestable results, or effects produced on various bodies. Thus, if one part, by weight of steam at 212°, be mixed with nine parts of water at 62°, the result is water at 178·6°; therefore, each of the 9 parts of water has received from the steam 116·6° of heat, and consequently, the steam has diffused, or given out, $116{\cdot}6 \times 9 = 1049{\cdot}4 - 33{\cdot}4 = 1016°$ of heat, which it must have contained.

Again; it is ascertained, by experiment, that if one gallon of water be transformed into steam at 212°, and that allowed to mix with water at 52°, the whole will be raised to the boiling point, or 212°. From these and other experiments, it is ascertained that the latent heat in steam varies from 940° to 1044°, the ratio of accumulation advancing from 212°, as the steam becomes more dense and of greater elastic force. Hence, the severity of a scald by steam to that of boiling water.

Water holding impurities in solution tends to retard its attaining the aëriform state, and so impairs the amount of its elastic force at an equal temperature, a,

exhibited in the following tables. Thus, common water boils at 212° Fahrenheit.

Name of substance.		Proportionate quantity in 100 parts by weight of water.	Boiling points.
Salts in sea water.		3·03.	213·2° F.
Sulphate of soda	In common water	31·5	213
Sulphate of iron		64	216
Alum		52	220
Sulphate of lime		45	220
Sulphate of magnesia . .		57·5	222
Muriate of soda		30	224
Nitrate of soda		60	246
Acetate of soda		60	256

Elastic Force of Steam in Inches of Mercury.

Common water	boiling point,	212° F.	elastic force,	30	in
Sea water . . .	at	212 "	"	23·05	"
Common water	boiling point,	216° F.	elastic force,	32·5	in.
Sea water . . .	at	216 "	"	24·6	"
Common water	boiling point,	220° F.	elastic force,	35·1	in.
Sea water . . .	at	220 "	"	26·5	"

Hence the propriety of procuring, for steam, water in its purest state.

Effects produced by Air in its natural and also in a rarefied State.

The weight or pressure of the atmosphere is equal to the weight of a column of water 34 feet in height, or to a column of mercury 30 inches in height, or to 14·7 lbs. average per square inch, at a mean temperature. But air, like all other gases, is rendered lighter by the application of heat; for then the particles of the mass are repelled from each other, or rarefied, and occupy a greater space. Rarefied air, being specifically lightest, mounts above that of common density; hence change of temperature, and the principal cause of winds.

Table of the Expansion of Atmospheric Air by Heat.

Degrees of Fahrenheit.	Bulk.	Degrees of Fahrenheit.	Bulk.	Degrees of Fahrenheit.	Bulk.
32°	1000	65°	1077	100°	1152
35	1007	70	1089	120	1194
40	1021	75	1099	140	1235
45	1032	80	1110	160	1275
50	1043	85	1121	180	1315
55	1055	90	1132	200	1364
60	1066	95	1142	212	1376

The pressure or gravity of the atmosphere, being equal to a column of water 34 feet in height, is the means or principle on which rests the utility of the common pump, also of the syphon and all other such hydraulic applications. In a pump, the internal pressure on the surface of the liquid is removed by the action of the bucket; and as by degrees the density becomes lessened, so the water rises by the external pressure to the above-named height; and at such height it will remain, unless, by some derangement of construction taking place, the atmospheric fluid is allowed to enter and displace the liquid column. But observe, if the temperature of the water or other liquid be so elevated that steam or vapor arise through it, then, according to the vapor's accumulation of density, may the action of the pump be partially or wholly destroyed; and the only means of evasion in such cases is, to place the working bucket beneath the surface of the liquid which is required to be raised.

Table showing the Quantity of Water per Lineal Foot in Pumps, or Vertical Pipes of different Diameters.

Diameter of pump in inches.	Number of gallons per lineal ft.	Number of cubic feet per lin. ft.	Diameter of pump in inches.	Number of gallons per lineal ft.	Number of cubic feet per lin ft.
2	·136	·0218	8	2·176	·3490
2¼	·172	·0276	8¼	2·314	·3712
2½	·212	·0340	8½	2·456	·3940
2¾	·257	·0412	8¾	2·603	·4175
3	·306	·0490	9	2·754	·4417
3¼	·359	·0576	9¼	2·909	·4666
3½	·416	·0668	9½	3·068	·4923
3¾	·478	·0766	9¾	3·232	·5184
4	·544	·0872	10	3·400	·5454
4¼	·614	·0985	10¼	3·572	5730
4½	·688	·1104	10½	3·748	·6013
4¾	·767	·1230	10¾	3·929	·6302
5	·850	·1363	11	4·114	·6599
5¼	·937	·1503	11¼	4·303	6902
5½	1·028	·1649	11½	4·496	·7212
5¾	1·124	·1803	11¾	4·694	·7529
6	1·224	·1963	12	4·896	·7853
6¼	1·328	·2130	12½	5·312	·8521
6½	1·436	·2304	13	5·746	·9217
6¾	1·549	·2489	13½	6·196	·9939
7	1·666	·2672	14	6·664	1·0689
7¼	1·787	·2866	15	7·650	1·2271
7½	1·912	·3067	16	8·704	1·3962
7¾	2·042	·3275	18	11·016	1·7670

Examples illustrative of the Utility of the Table.

1. Required the quantity of water lifted by each stroke of the bucket of a 9½-inch pump, the length of the stroke being 2¼ feet.

$3{\cdot}068 \times 2{\cdot}25 = 6{\cdot}903$ gallons, each stroke.

2. What length of stroke with a 6-inch pump will be necessary, to discharge 44 gallons of water per

minute, the number of strokes being 18 in the given time?

$$\frac{44}{1{\cdot}224 \times 18} = 2 \text{ feet, the length of stroke.}$$

3. What must be the diameter capable of raising 25 cubic feet of water per minute, the length of the stroke being $2\frac{1}{2}$ feet, and making 16 effective strokes per minute?

$$\frac{25}{2{\cdot}5 \times 16} = {\cdot}625, \text{ or } 10\tfrac{3}{4} \text{ inches, nearly.}$$

It is by the oxygen of the atmosphere that combustion is supported. The common combustibles of nature are chiefly compounds of carbon and hydrogen, which, during combustion, combine with the oxygen of the atmosphere, and are converted into carbonic acid and watery vapor, different species of fuel requiring different quantities of oxygen. The quantity required for the combustion of a pound of coal varies from 2 to 3 lbs., according to the quality of the coal. 60 cubic feet of atmospheric air is necessary, to produce 1 lb. of oxygen.

The pressure or fluid properties of the atmosphere oppose bodies in passing through it, the opposing resistance increasing as the square of the velocity of the body, and the resistance per square foot in lbs. as its velocity in feet per second, multiplied into ·002288. Thus, suppose a locomotive engine in a still atmosphere, at a velocity of 25 miles per hour, presents a resisting frontage of 20 feet; required the amount of opposing resistance at that velocity.

25 miles per hour equal 36·67 feet per second.

Then $36{\cdot}67^2 \times {\cdot}002288 \times 20 = 61{\cdot}5$ lbs., constant opposing force

Table of the Force and common Appellations given to Winds at different Velocities.

Velocity of the Wind in		Force in lbs. avoirdupois per square foot.	Common Appellations given to the Wind.
Miles per hour.	Feet per second.		
1	1·47	·005	Hardly perceptible.
2	2·93	·020	Just perceptible.
3	4·40	·044	
4	5·87	·079	Gentle, pleasant wind.
5	7·33	·123	
10	14·67	·492	Pleasant, brisk gale.
15	22·00	1·107	
20	29·34	1·968	Very brisk.
25	36·67	3·075	
30	44·01	4·429	High winds.
35	51·34	6·027	
40	58·68	7·873	Very high.
45	66·01	9·963	
50	73·35	12·300	A storm or tempest.
60	88·02	17·715	A great storm.
80	117·36	31·490	A hurricane..

In order to gain the greatest amount of the wind's impulsive effect, to produce rotary or circular motion by the sails of a wind-mill, the total surface of the sails presented to the wind ought to be about seven-eighths of the circle's surface which is formed by their motion, and each sail angled to the plane of motion as follows, the whip or back being divided into six equal parts:—

Distance from centre of motion,	1	2	3	4	5	6	Smeaton's rule.
Angle with plane of motion,	18°	19	18	16	12½	7	
By G. Forrester, Liverpool,	24°	21	18	14	9	3	

FRICTION.

Friction is an effect produced by bodies rubbing one upon another, which acts as a retarding influence in the motion of all mechanical contrivances, but might not unfrequently be considerably diminished by a due regard to its laws, and a proper attention to the selection of those materials on which a uniform smooth surface may be attained, and which, according to experiments, are least liable to tear or become hot, and cause a roughness to arise when in working contact.

Several doubts existed, until lately, respecting the laws of friction; but those are now entirely removed, through the experiments of Mr. G. Rennie, on his own account, and those of M. Morin, acting for, and under the sanction of, the French government, from or by which the following laws have been fully established: —

1. The friction accompanying the motion of two surfaces, between which no unguent is interposed, bears the same proportion to the force by which those surfaces are pressed together, whatever may be the amount of that force.

2. This friction is independent of the extent of the surfaces of contact.

3. Where unguents are interposed, a distinction is to be made between the case in which the surfaces are simply unctuous and in intimate contact with one another, and the case in which the surfaces are wholly separated from one another by an interposed stratum of the unguent. If the pressure upon a surface of contact of given dimensions be increased beyond a certain limit, the latter of these cases passes into the first; the stratum of unguent being pressed out, and the unctuous surfaces, which it separated from one

another, being brought into intimate contact. As long as either of these two states remain, the laws of its friction are not affected by the presence of the unguent: but, in the transition from the one state to the other, an exception is made to the independence of the friction upon the extent of the surface of contact; for, supposing the extent of two surfaces of contact, between which a stratum of unguent is interposed, and which sustain a given pressure, to be continually diminished, it is evident, that the portions of this pressure which take effect upon each element of the surfaces of contact will be continually increased, and that they may thus be so increased as to press out the interposed stratum of unguent, and cause the state of the surfaces to pass into that which is designated as unctuous, thereby changing the coëfficient of friction. That law of friction, then, which is known as the law of : : the independence of the surface, is to be received, in the case where a stratum of unguents is interposed, only within certain limits.

It will be understood, from what has been said, that there are three states, in respect to friction, into which the surfaces of bodies in contact may be made successively to pass: one, a state in which no unguent is present; the second, a state in which the surfaces are unctuous, but intimately in contact; the third, a state in which the surfaces are separated by an entire stratum of the interposed unguent.

Throughout each of these states, the coëfficient of friction is the same; but it is essentially different in the different states.

4. It is a law common to the friction of all the states of contact of two surfaces, that their friction, when in motion, is altogether independent of the velocity of the motion. M Morin has verified this law, as well in various states of contact without interposed fluids, as in the cases where water, oils, grease, glutinous liquids, sirups, pitch, were interposed in a continuous stratum.

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The variety of the circumstances under which these laws obtain in respect to the friction of motion, and the accuracy with which the phenomena of motion accord with them, may be judged of from one example, taken from the first set of experiments of M. Morin upon the friction of surfaces of oak, whose fibres were parallel to the direction of their motion upon one another. He caused the surfaces of contact to vary their dimensions in the ratio of 1 to 84, — from less than 5 square inches to nearly 3 feet square; the forces which pressed them together he varied from 88 lbs. to 2205 lbs., and their velocities from the slowest possible to 9·8 feet per second, — causing them to be at one period accelerated motions, at another uniform, at a third retarded; yet, through all this wide range of variation, he in no instance found the coefficient of friction to deviate from the same fraction of 0·478 by more than $\frac{1}{24}$ of the amount of the fraction.

RULES, TABLES, ETC., RELATIVE TO BOILERS AND THE STEAM-ENGINE.

The *boiler of a steam-engine* may be explained as that portion of the structure in which the vital principle of the engine is generated; consequently, its construction is of the utmost importance; for upon the proper efficiency of the boiler depends, in a great measure, the efficiency of the engine.

Boilers not unfrequently, because of unavoidable peculiarities, are necessarily constructed of various forms; but, for land or stationary engine boilers, if no thwarting circumstances intervene, either the wagon or cylindrical forms are commonly resorted to; the

former for those of condensing engines, and the latter for those of the high-pressure principle.

In the construction of boilers, much attention ought to be paid in avoiding thin films of water where the action of the fire is great; because it is neither consistent with safety, nor can there be the proper quantities of steam generated, according to the surface exposed, unless under some extraordinary degree of pressure. Also, convex surfaces, exposed to the action of the steam, unless properly supported, ought strenuously to be avoided. Large water spaces, concave surfaces, or straight plates securely stayed, with ample steam-room, are the chief requisites to be attended to.

1. *To determine the proper quantity of heating surface in a boiler for an engine with a cylinder of a given capacity, and steam at any density required.*

Rule. — Multiply 375 times the area of the cylinder in feet by the velocity of the piston in feet per minute, and divide the product by the volume of steam to 1 of water at the density required, (see Table, page 91;) and the quotient is the amount of effective heating surface in square feet.

Ex. Required the amount of effective heating surface in a boiler for an engine whose cylinder is $4\frac{1}{2}$ square feet in area, and the piston's velocity 224 feet per minute, the pressure of the steam to equal 5 lbs. per square inch above the pressure of the atmosphere.

$\frac{375 \times 4{\cdot}5 \times 224}{1282} = 295$ square feet, nearly; the fire-grate being in accordance with the following rule.

Multiply the number of square feet of heating surface by ·12, the product equal the area of fire-grate in square feet, thus: —

$295 \times {\cdot}12 = 35{\cdot}4$ square feet of furnace bar.

Note. — By *effective heating surface* is meant horizontal surfaces over fire, flame, or heated air; vertical or side surfaces requiring about $1\frac{3}{4}$ feet to equal in effect 1 of horizontal surface.

2. *To determine the proper dimensions for a wagon-shaped boiler, when the amount of effective heating surface in square feet is obtained by the preceding rule.*

1. The bottom surface equal half the whole surface
2. The length of the boiler equal twice the square root of bottom surface.
3. The width equal one-fourth the length; and
4. The height equal one-third the length.

Ex. Required the dimensions for a boiler of the wagon form, that may present an effective heating surface of 295 square feet.

Bottom surface $= 295 \div 2$, or 147·5 square feet.
Length . . . $= \sqrt{147 \cdot 5} \times 2$, or 24·26 feet.
Width . . . $= 24 \cdot 26 \div 4$, or 6·06 feet.
Height . . . $= 24 \cdot 26 \div 3$, or 8·08 feet.

Note.—The amount of side or vertical surface equal twice the length of the boiler, added to the width, and multiplied by ·75 to obtain that of effective surface; hence,

$$\frac{147 \cdot 5 \times 1 \cdot 75}{24 \cdot 26 \times 2 + 6 \cdot 06} = 4 \cdot 7 \text{ feet, depth of side flue.}$$

3. *To determine the dimensions for a cylindrical boiler.*

Rule.—Extract the square root of 1·34 times the effective heating surface in square feet, and twice the root equal the boiler's circumference in feet; also, the circumference equal the length.

Ex. Let a cylindrical boiler be required with an effective heating surface of 86 square feet; what must be its length and diameter in feet?

$\sqrt{86 \times 1 \cdot 34} = 10 \cdot 74 \times 2 = 21 \cdot 48$ feet circumference, or 6 feet 10 inches diameter, and 21·48 feet in length.

Note.—When an internal flue is to be inserted in a boiler the external surface of the boiler may be diminished in length

equal to half the exposed surface of the flue. Observe, also, that the height of the contained water in boilers generally ought to be about two-thirds the whole height of the boiler

Specified Particulars relative to the Boiler and Engine.

Diameter of cylinders, ...	14 inches.
Length of stroke, ...	18 "
Lap of the valve, ...	1 inch.
Diameter of driving wheels, ...	5½ feet.
Length of internal fire-box, . . .	2 feet 11½ inches.
Width of do., ...	3 " 5 "
Length of cylindrical part of boiler,	8 " 8 "
Diameter of do., ...	3 " 4½ "
Length of tubes, ...	8 " 11½ "
Number of tubes, ...	133, of brass.
Interior diameter of do., ...	1¾ inches.
Diameter of blast-pipe, ...	4 "

About 112 lbs. of coke, consumed in this boiler evaporate 84 gallons of water; and from 20 to 25 lbs of coke are consumed per mile.

Heating Powers of Combustible Substances

Species of combustible.	lbs. of water heated from 32° to 212°.	lbs. of boiling water evaporated by 1 lb. of fuel.	lbs. of atmospheric air to each lb. of fuel.
Wood in its ordinary state	26	4·72	4·47
Wood charcoal	73	13·37	11·46
Coal	60	10·90	9·26
Coke	65	11·81	11·46
Turf	30	5·45	4·60
Turf charcoal	64	11·63	9·86

Table of Dimensions for Steam-Engine Cylinders by celebrated Makers.

Stationary Condensing Engines, by Boulton & Watt.			Marine Engines, by Maudsley, Napier, &c.			High-Pressure, or Non-Condensing Engines, by various makers.				
Nominal horses' power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horses' power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horses' power.	Diameters of cylinders, the force of the steam being, per square inch, 25 lbs.	30 lbs.	40 lbs.	50 lbs.
6	14½	3	10	20	2	1	3¾	3½	3	2¾
8	16¼	3	15	24	2¼	2	5¼	4¾	4¼	3¾
10	18	3½	20	27	2½	3	6½	6	5	4½
12	19½	4	25	29½	2¾	4	7½	6¾	6	5¼
14	21	4½	30	32	3	5	8¼	7½	6½	5⅞
16	22½	4½	40	36	3½	6	9	8¼	7¼	6½
18	23½	5	50	40	4	7	9¾	9	7¾	6⅞
20	24½	5	60	43	4	8	10½	9¾	8½	7½
22	26	5	70	46½	4½	9	11⅛	10¼	8¾	7⅞
24	27	5½	80	47½	4½	10	11¾	11	9½	8½
25	27½	5½	90	50	4¾	11	12¼	11⅜	9¾	8¾
26	28	5¾	100	53	5	12	13	12	10½	9¼
28	29	6	110	55½	5½	14	14	12¾	11¼	10
30	30	6	120	57	5½	16	15	13¾	12	10½
35	32½	6½	130	60¾	5¾	18	15¾	14½	12¾	11¼
40	34½	6½	150	65	6	20	16¾	15¼	13½	11¾
50	38½	7	200	74½	6	25	18½	17¼	15	13¼
60	42¼	7	250	84	6	30	20¼	19¾	16¼	14½

The *unit* of nominal power for steam-engines, or the usual estimate of dynamical effect per minute of a horse, called, by engineers, *a horse-power*, is 33,000 lbs., at a velocity of 1 foot per minute; or, the effect of a load of 200 lbs., raised by a horse, for 8 hours a day, at the rate of 2½ miles per hour, or 150 lbs. at the rate of 220 feet per minute.

PROPERTIES OF BODIES.

Tables, combining the Specific Gravities and other Properties of Bodies. Water the Standard of Comparison, or 1000.

METALS.

Names.	Specific gravity.	Melting points in degrees of Fahrenheit.	Contraction in parts of an inch per lineal foot from the fluid to the average temperature in solid state.	Ultimate cohesive strength of an inch sq. prism in tons.	Scale of wire-drawing ductility.	Scale of laminable ductility.	Ratio of hardness.	Scale as conductors of electricity.	Ratio of power in the conduction of heat.
Platinum	19500	3280	—	—	3	5	—	—	3·8
Pure Gold	19258	2016	—	—	1	1	1·8	3	10·0
Mercury	13500	—	—	—	—	—	—	—	—
Lead	11352	612	·319	·81	8	7	1·0	6	1·8
Pure Silver . . .	10474	1873	—	—	2	2	2·4	2	9·7
Bismuth	9823	476	·156	1·45	—	—	2·0	—	—
Copper, cast . .	8788	1996	·193	8·51	—	—	—	—	—
" wrought	8910	—	—	15·08	5	3	2·8	1	8·9
Brass, cast . . .	7824	1900	·210	8·01	—	—	to any degree	—	—
" sheet .	8396	—	—	12·23	6	6	—	—	8·6
Iron, cast	7264	2786	·125	7·87	—	—	to any degree	—	—
" bar	7700	—	·137	25·00	4	8	4·7	4	3·7
Steel, soft	7833	—	·133	58·91	—	—	—	—	—
" hard . . .	7816	—	—	—	—	—	to any degree	—	—
Tin, cast	7291	442	·278	2·11	8	4	1·2	5	3·0
Zinc, cast	7190	773	·329	5·06	7	8	1·6	7	3·6

STONES, EARTHS, &c.

Names.	Specific gravity.	Weight of a cubic foot in lbs.	Cubic feet in a ton.	Tons required to crush 1½-inch cubes.
Marble, average	2720	170·00	13	9·25
Granite, do. . .	2651	165·68	13⅕	6·2
Purbeck stone .	2601	162·56	13¾	9·0
Portland do. . .	2570	160·62	14	4·5
Bristol do. . . .	2554	159·62	14	—
Millstone	2484	155·25	14⅕	—
Paving stone . .	2415	150·93	14¾	5·7
Craigleith do.. .	2362	147·62	15	5·0
Grindstone . . .	2143	133·93	16¾	6·6
Chalk, Brit.. . .	2781	173·81	12¾	0·5
Brick	2000	125·00	17	0·8
Coal, Scotch . .	1300	81·15	27⅕	—
" Newcastle	1270	79·37	27¼	—
" Staffordsh.	1240	77·50	29	—
" Cannel . .	1238	77·37	29	—

WOODS							
Names.	Specific gravity, water, 1000.	Average wt. of a cubic ft. in lbs.	Cubic feet in a ton.	Ultimate cohesive strength of an inch square prism in lbs.	Comparative Stiffness.	Comparative Strength.	Comparative Resilience.
English oak	934	58	38½	11880	100	100	100
Riga do.	872	54	41½	12888	93	108	125
Dantzic do.	756	47	48	12780	117	107	99
American do.	672	42	53	10253	114	86	64
Beech	852	48	45	12225	77	103	138
Alder	800	46	48½	9540	63	80	101
Plane	640	40	55	10935	78	92	108
Sycamore	604	38	59	9630	59	81	111
Chestnut	610	38	59	10656	67	89	118
Ash	845	52	43	14130	89	119	160
Elm	673	42	53	9720	78	82	86
Mahogany, Spanish	800	50	45	7560	73	67	61
" Honduras	637	40	55	11475	93	96	99
Walnut	671	42	53	8800	49	74	111
Teak	750	46	48½	12915	126	109	94
Poona	640	40	55	12350	99	104	82
African oak	944	59	38	17200	101	144	138
Poplar	383	34	66	5928	44	50	57
Cedar	561	33	68	7420	28	62	106
Riga fir	753	47	48	9540	98	80	64
Memel do.	546	34	66	9540	114	80	56
Scotch do.	528	33	68	7110	55	60	65
Christ. Wht. deal	590	37	60	12346	104	104	104
Amern. white spruce	551	34	66	10296	72	86	102
Yellow pine	461	28	80	11853	95	99	103
Pitch pine	660	41	54½	9796	73	82	92
Larch	530	31	72	12240	79	103	134
Cork	240	15	149	—	—	—	—

LIQUIDS.		
Names.	Specific gravity, water, 1000.	Weight of an imperial gallon in lbs.
Acid, sulphuric	1850	18·5
" nitric . .	1271	12·7
" muriatic .	1200	12·0
" fluoric . .	1060	10·6
" citric . .	1034	10·3
" acetic . .	1062	10·6
Water from the Baltic	1015	10·2
Water from the Dead Sea . . .	1240	12·4
Water from the Mediterranean	1029	10·3
Water, distilled	1000	10·0
Oils, expressed :		
linseed	940	9·4
sweet almond	932	9·3
whale	923	9·2
hempseed . .	926	9·3
olive	915	9·2
Oils, essential :		
cinnamon . .	1043	10·4
lavender . . .	894	8·9
turpentine . .	870	8·7
amber	868	8·7
Alcohol	825	8·2
Ether, nitric . .	908	9·1
Proof spirit . .	922	9·2
Vinegar	1009	10·1

GASES. Atmospheric air being the standard of comparison, or 1000.	
Names.	Specific gravity.
Hydriodic acid gas	4340
Chlorine " "	2500
Carbonic " "	1527
Nitrous oxide "	1527
Cyanogen "	1805
Oxygen "	1111
Carbonic oxide "	972
Carbureted hydrogen "	972
Prussic acid "	937
Ammoniacal "	590
Steam of water "	623
Hydrogen "	69

Weight of water at the common temperature :

1 cubic in. = ·03617 lb.
1 " ft. = 62·5 lbs.
1 " " = 6·25 imp. galls.
1·8 " " = 1 cwt.
1 cylin. in. = ·02842 lb.
1 " ft. = 49·1 lbs.
1 " " = 5 imp. galls.
2·282 feet = 1 cwt.
11·2 imp. galls. = 1 cwt.
224 " " = 1 ton.

PRACTICAL TABLES.

WEIGHT OF METALS.

WROUGHT IRON; SQUARE, ROUND, AND FLAT.

Table I. contains the weight of Square Iron in sizes, from ¼ inch to six inches square, advancing by ⅛ inch; and from 6 to 12 inches square, advancing by ¼ inch; and in lengths, from 1 foot to 18 feet. The sizes are arranged in the first column of each page, and the lengths along the top; the weight in lbs. immediately under the lengths, and in a line with the sizes.

Table II. contains the weight of Round Iron in sizes from ¼ inch to 6 inches diameter, advancing by ⅛ inch; and from 6 to 12 inches diameter, advancing by ¼ inch; and in lengths from 1 foot to 18 feet. The sizes, lengths, and weights are arranged as in Table I.

Table III. contains the weight of Flat Iron in widths, from ¼ inch to 6 inches diameter, advancing by ¼ inch; in thicknesses from ¼ inch to 1 inch, advancing by ⅛ inch; and in lengths, from 1. to 18 feet. The widths, lengths, and weights, are arranged as in the preceding tables, and the thicknesses alongside of the widths.

TABLE I.—SQUARE IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs
¼	0·2	0 4	0·6	0·8	1·1	1 3	1·5	1·7	1 9
⅜	0·5	1 0	1 4	1·9	2·4	2·9	3·3	3·8	4·3
½	0·8	1 7	2·5	3·4	4·2	5·1	5·9	6·8	7·6
⅝	1·3	2·6	4·0	5·3	6·6	7·9	9·2	10·6	11·9
¾	1·9	3·8	5·7	7·6	9·5	11·4	13·3	15·2	17·1
⅞	2·6	5·2	7·8	10·4	12·9	15·5	18·1	20·7	23·3
1	3·4	6·8	10·1	13·5	16·9	20·3	23·7	27·0	30·4
1⅛	4·3	8·6	12·8	17·1	21·4	25·7	29·9	34·2	38·5
1¼	5·3	10·6	15·8	21·1	26·4	31·7	37·0	42·2	47·5
1⅜	6·4	12·8	19·2	25·6	32·0	38·3	44·7	51·1	57·5
1½	7·6	15·2	22·8	30·4	38·0	45·6	53·2	60·8	68·4
1⅝	8·9	17·9	26·8	35·7	44·6	53·6	62·5	71·4	80·3
1¾	10·4	20·7	31·1	41·4	51·8	62·1	72·5	82·8	93·2
1⅞	11·9	23·8	35·6	47·5	59·4	71·3	83·2	95·1	106·9
2	13·5	27·0	40·6	54·1	67·6	81·1	94·6	108·2	121·7
2⅛	15·3	30·5	45·8	61·1	76·3	91·6	106·8	122·1	137·4
2¼	17 1	34·2	51·3	68·4	85·6	102·7	119·8	136·9	154·0
2⅜	19·1	38·1	57·2	76·3	95·3	114·4	133·5	152·5	171·6
2½	21·1	42·2	63·4	84·5	105·6	126·7	147·8	169·0	190·1
2⅝	23·3	46·6	69·9	93·2	116·5	139·8	163·0	186·3	209·6
2¾	25·6	51·1	76 7	102·2	127·8	153·4	178·9	204·5	230·0
2⅞	27·9	55·9	83·8	111·8	139·7	167 6	195·7	223·5	251·5
3	30·4	60·8	91·2	121·7	152·1	182·5	212·9	243·3	273·7
3⅛	33·0	66·0	99·0	132·0	165·1	198·1	231·1	264·1	297·1
3¼	35·7	71·4	107·1	142·8	178·5	214·2	249·9	285·6	321·3
3⅜	38·5	77·0	115·5	154·0	192·5	231·0	269·5	308·0	346·5
3½	41·4	82·8	124·2	165·6	207·0	248·4	289·8	331·3	372·7
3⅝	44·4	88·8	133·3	177·7	222·1	266·5	310·9	355·3	399·8
3¾	47·5	95·1	142·6	190·1	237 7	285·2	332 7	380·3	427·8
3⅞	50·8	101·5	152·3	203·0	253·8	304·5	355·3	406·0	456·8

TABLE I.—SQUARE IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	2·1	2·3	2·5	2·7	3·0	3·2	3·4	3·6	3·8
⅜	4·8	5·2	5·7	6·2	6·7	7·1	7·6	8·1	8·6
½	8·5	9·3	10·1	11·0	11·8	12·0	13·5	14·4	15·2
⅝	13·2	14·5	15·8	17·2	18·5	19·8	21·1	22·4	23·8
¾	19·0	20·9	22·8	24·7	26·6	28·5	30·4	32·3	34·2
⅞	25·9	28·5	31·1	33·6	36·2	38·8	41·4	44·0	46·6
1	33·8	37·2	40·6	43·9	47·3	50·7	54·1	57·5	60·8
1⅛	42·8	47·1	51·3	55·6	59·9	64·2	68·4	72·7	77·0
1¼	52·8	58·1	63·4	68·6	73·9	79·2	84·5	89·8	95·0
1⅜	63·9	70·3	76·7	83·1	89·5	95·9	102·2	108·6	115·0
1½	76·0	83·6	91·2	98·9	106·5	114·1	121·7	129·3	136·9
1⅝	89·3	98·2	107·1	116·0	125·0	133·9	142·8	151·7	160·7
1¾	103·5	133·9	124·2	134·6	144·9	155·3	165·6	176·0	186·3
1⅞	118·8	130·7	142·6	154·5	166·4	178·2	190·1	202·0	213·9
2	135·2	148·7	162·2	175·8	189·3	202·8	216·3	229·8	243·4
2⅛	152·6	167·9	183·2	198·4	213·7	228 9	244·2	259·5	274·7
2¼	171·1	188·2	205·3	222·5	239·6	256·7	273·8	290·9	308·0
2⅜	190·7	209·7	228·8	247·9	266·9	286·0	305·1	324·1	343·2
2½	211·2	232·3	253·4	274·6	295·7	316·8	337·9	359·0	380·2
2⅝	232·9	256·2	279·5	302·8	326·1	349·4	372·7	396·0	419·3
2¾	255·6	281·2	306·7	332·3	357·8	383·4	409·0	434·5	460·1
2⅞	279·4	307·3	335·3	363·2	391·1	419·1	447·0	475·0	502·9
3	304·2	334·6	365·0	395·4	425·8	456·2	486·7	517·1	547·5
3⅛	330·1	363·1	396·1	429·1	462·1	495·2	528·2	561·2	594·2
3¼	357·0	392·7	428·4	464·2	499·9	535·6	571·3	607·0	642·7
3⅜	385·0	423·5	462·0	500·5	539·0	577·5	616·0	654·6	693·1
3½	414·1	455·5	496·9	538·3	579·7	621·1	662·5	703·9	745·3
3⅝	444·2	488·6	533·0	577·4	621·9	666·3	710·7	755·1	799·5
3¾	475·3	522·9	570·4	617·9	665·5	713·0	760·5	808·1	855·6
3⅞	507·6	558·3	609·1	659·8	710·6	761·3	812·1	862·9	913·6

TABLE I.—SQUARE IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft	8 ft.	9 ft.
inch	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	54·1	108·2	162·3	216·3	270·4	324·5	378·6	432·7	486·8
4⅛	57·5	115·0	172·6	230·1	287·6	345·1	402·6	460·1	517·7
4¼	61·1	122·1	183·2	244·2	305·3	366·3	427·4	488·4	549·5
4⅜	64·7	129·4	194·1	258·8	323·5	388·2	452·9	517·6	582·3
4½	68·4	136·9	205·3	273·8	342·2	410·7	479·1	547·6	616·0
4⅝	72·3	144·6	216·9	289·2	361·5	433·8	506·1	578·4	650·7
4¾	76·3	152·5	228·8	305·1	381·3	457·6	533·8	610·1	686·4
4⅞	80·3	160·7	241·0	321·3	401·7	482·0	562·3	642·7	723·0
5	84·5	169·0	253·4	337·9	422·4	506·9	591·4	675·8	760·3
5⅛	88·8	177·6	266·4	355·1	443·9	532·7	621·5	710·3	799·1
5¼	93·2	186·3	279·5	372·7	465·8	559·0	652·2	745·3	838·5
5⅜	97·7	195·3	293·0	390·6	488·3	585·9	683·6	781·3	878·9
5½	102·2	204·5	306·7	409·0	511·2	613·4	715·7	817·9	920·2
5⅝	107·0	213·5	320·9	427·8	534·8	641·7	748·7	855·6	962·6
5¾	111·8	223·5	335·3	447·0	558·8	670·5	782·3	894·0	1005·8
5⅞	116·7	233·3	350·0	466·7	583·4	700·0	816·7	933·4	1050·0
6	121·7	243·3	365·0	486·7	608·3	730·0	841·6	973·3	1095·0
6¼	132·0	264·1	396·1	528·2	660·2	792·2	924·3	1056·3	1188·4
6½	142·8	285·6	428·4	571·3	714·1	856·9	999·7	1142·5	1285·3
6¾	154·0	308·0	462·0	616·0	770·1	924·1	1078·1	1232·1	1386·1
7	165·6	331·2	496·9	662·5	828·2	993·8	1159·4	1325·1	1490·7
7¼	177·7	355·3	533·0	710·7	888·4	1066·0	1243·7	1421·4	1599·0
7½	190·1	380·3	570·4	760·5	950·7	1140·8	1331·0	1521·1	1711·2
7¾	203·0	406·0	609·1	812·1	1015·1	1218·1	1421·2	1624·2	1827·2
8	216·3	432·7	649·0	865·3	1081·7	1298·0	1514·4	1730·7	1947·0
8¼	230·1	460·1	690·2	920·3	1150·3	1380·4	1610·5	1840·5	2070·6
8½	244·2	488·4	732·7	976·9	1221·1	1465·3	1709·5	1953·8	2198·0
8¾	258·8	517·6	776·4	1035·2	1294·0	1552·8	1811·6	2070·4	2329·2
9	273·8	547·6	821·4	1095·2	1369·0	1642·8	1916·5	2190·3	2464·1

TABLE I.—SQUARE IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	540·8	594·9	649·0	703·1	757·2	811·3	865·3	919·4	973·5
$4\frac{1}{8}$	575·2	632·7	690·2	747·7	805·2	862·8	920·3	977·8	1035·3
$4\frac{1}{4}$	610·6	671·6	732·7	793·7	854·8	915·8	976·9	1037·9	1099·0
$4\frac{3}{8}$	646·0	711·7	776·4	841·1	905·8	970·5	1035·2	1099·9	1164·6
$4\frac{1}{2}$	684·5	752·9	821·4	889·8	958·3	1026·7	1095·2	1163·6	1232·1
$4\frac{5}{8}$	723·1	795·4	867·7	940·0	1012·3	1084·6	1156·9	1229·2	1301·5
$4\frac{3}{4}$	762·6	838·9	915·2	991·4	1067·7	1144·0	1220·2	1296·5	1372·8
$4\frac{7}{8}$	803·3	883·7	964·0	1044·3	1124·7	1205·0	1285·3	1365·7	1446·0
5	844·8	929·3	1013·8	1098·2	1182·7	1267·2	1351·7	1436·2	1520·6
$5\frac{1}{8}$	887·8	976·6	1065·4	1154·2	1243·0	1331·8	1420·5	1509·3	1598·1
$5\frac{1}{4}$	931·7	1024·8	1118·0	1211·2	1304·4	1397·5	1490·7	1583·9	1677·0
$5\frac{3}{8}$	976·6	1074·2	1171·9	1269·5	1367·2	1464·9	1562·5	1660·2	1757·8
$5\frac{1}{2}$	1022·4	1124·6	1226·9	1329·1	1431·4	1533·6	1635·8	1738·1	1840·3
$5\frac{5}{8}$	1069·5	1176·5	1283·4	1390·4	1497·3	1604·3	1711·2	1818·2	1925·2
$5\frac{3}{4}$	1117·6	1229·3	1341·1	1452·8	1564·6	1676·3	1788·1	1899·9	2011·6
$5\frac{7}{8}$	1160·0	1283·4	1400·1	1516·7	1633·4	1750·1	1866·7	1983·4	2100·1
6	1229 6	1338·3	1460·0	1581·6	1703·3	1825·0	1946·6	2068·3	2190·0
$6\frac{1}{4}$	1320·4	1452·4	1584·4	1716·5	1848·6	1980·6	2112·6	2244·7	2376·7
$6\frac{1}{2}$	1428·2	1571·0	1713·8	1856·6	1999·4	2142·2	2285·1	2427·9	2570·7
$6\frac{3}{4}$	1540·1	1694·1	1848·1	2002·2	2056·2	2310·2	2464·2	2618·2	2772·2
7	1656·3	1822·0	1987·6	2153·2	2318·8	2484·5	2650·1	2815·7	2981·4
$7\frac{1}{4}$	1776·7	1954·4	2132 1	2309·7	2487·4	2665·1	2842·8	3020·4	3198·1
$7\frac{1}{2}$	1901·4	2091·5	2281·6	2471·8	2661·9	2852·0	3042·2	3232·3	3422·4
$7\frac{3}{4}$	2030·2	2233·3	2436·3	2639·3	2842·3	3045·4	3248·4	3451·4	3654·4
8	2163·4	2379·7	2596·0	2812·4	3028·7	3245·0	3461·4	3677·7	3894·0
$8\frac{1}{4}$	2300·7	2530·7	2760·8	2990·9	3220·9	3451·0	3681·1	3911·1	4141·2
$8\frac{1}{2}$	2442·2	2686·4	2930·6	3174·9	3419·1	3663·3	3907·5	4151·7	4396·0
$8\frac{3}{4}$	2588·0	2846·8	3105·6	3364·4	3623·2	3882·0	4140·8	4399·6	4658·4
9	2737·9	3011·7	3285·5	3559·3	3833·1	4106·9	4380·7	4654·5	4928·3

TABLE I.—SQUARE IRON

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9¼	289·2	578·4	867·7	1156·9	1446·1	1735·3	2024·5	2313·8	2603·0
9½	305·1	610·1	915·2	1220·2	1525·3	1830·3	2135·4	2440·4	2745·5
9¾	321·3	642·7	964·0	1285·3	1606·7	1928·0	2249·3	2570·7	2892·3
10	337·9	675·8	1013·8	1351·7	1689·6	2027·5	2365·4	2703·4	3041·0
10¼	355·1	710·3	1065·4	1420·5	1775·7	2130·8	2486·0	2841·1	3196·2
10½	372·7	745·3	1118·0	1490·7	1863·4	2236·0	2608·7	2981·4	3354·0
10¾	390·6	781·3	1171·9	1562·5	1953·1	2343·8	2734·4	3125·0	3515·7
11	409·0	817·9	1226·9	1635·8	2044·8	2453·8	2862·7	3271·7	3680·6
11¼	427·8	855·6	1283·4	1711·2	2139·1	2566·9	2994·7	3422·5	3850·3
11½	447·0	894·0	1341·1	1788·1	2235·1	2682·1	3129·2	3576·2	4023·2
11¾	466·7	933·4	1400·1	1866·7	2333·4	2800·1	3266·8	3733·5	4200·2
12	486·7	973·3	1460·0	1946·6	2433·3	2919·9	3406·6	3893·2	4379·9

TABLE I.—SQUARE IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9¼	2892·2	3181·4	3470·6	3759·9	4049·1	4338·3	4627·5	4916·7	5206·0
9½	3050·6	3355·6	3660·7	3965·7	4270·8	4575·8	4880·9	5186·0	5491·0
9¾	3213·3	3534·7	3856·4	4177·3	4498·6	4820·0	5141·3	5462·6	5784·0
10	3379·2	3717·1	4055·0	4393·0	4730·9	5068·8	5406·7	5744·6	6082·6
10¼	3551·4	3906·5	4261·6	4616·8	4971·9	5327·0	5682·2	6037·3	6392·4
10½	3726·7	4099·4	4472·1	4844·7	5217·4	5590·1	5962·8	6335·4	6708·1
10¾	3906·3	4297·0	4687·5	5078·2	5468·8	5859·4	6250·0	6644·7	7031·3
11	4089·6	4498·6	4907·5	5316·5	5725·4	6134·4	6543·4	6952·3	7361·3
11¼	4278·1	4705·9	5133·7	5561·6	5989·4	6417·2	6845·0	7272·8	7700·6
11½	4470·2	4917·3	5364·3	5811·3	6258·3	6705·4	7152·4	7599·4	8046·4
11¾	4666·8	5133·5	5600·2	6066·9	6533·6	7000·3	7466·9	7933·6	8400·3
12	4866·6	5353·2	5839·9	6326·5	6813·2	7299·8	7786·5	8273·2	8759·8

TABLE II.—ROUND IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	0·2	0·3	0·5	0·7	0·8	1·0	1·2	1·3	1.5
⅜	0·4	0·7	1·1	1·5	1·9	2·2	2·6	3·0	3·4
½	0·7	1·3	2·0	2·7	3·3	4·0	4·6	5·3	6·0
⅝	1·0	2·1	3·1	4·2	5·2	6·3	7·3	8·3	9·4
¾	1·5	3·0	4·5	6·0	7·5	9·0	10·5	11·9	13·4
⅞	2·0	4·1	6·1	8·1	10·2	12·2	14·2	16·3	18·3
1	2·7	5·3	8·0	10·6	13·3	15·9	18·6	21·2	23·9
1⅛	3·4	6·7	10·1	13·4	16·8	20·2	23·5	26·9	30·2
1¼	4·2	8·3	12·5	16·7	20·9	25·0	29·2	33·4	37·5
1⅜	5·0	10·0	15·1	20·1	25·1	30·1	35·1	40·2	45·2
1½	6·0	11·9	17·9	23·9	29·9	35·8	41·8	47·8	53·7
1⅝	7·0	14·0	21·0	28·0	35·1	42·1	49·1	56·1	63·1
1¾	8·1	16·3	24·4	32·5	40·6	48·8	56·9	65·0	73·2
1⅞	9·3	18·7	28·0	37·3	46·7	56·0	65·3	74·7	84·0
2	10·6	21·2	31·8	42·5	53·1	63·7	74·3	84·9	95·5
2⅛	12·0	24·0	36·0	48 0	59·9	71·9	83·9	95·9	107·9
2¼	13·5	26·9	40·3	53·8	67·2	80·6	94·1	107·5	121·0
2⅜	15·0	30·0	44·9	60·0	74·9	89·9	104·8	119·8	134·8
2½	16·7	33·4	50·1	66·8	83·4	100·1	116·8	133·5	150·2
2⅝	18·8	36·6	54·9	73·2	91·5	109·8	128·1	146·3	164·6
2¾	20·1	40·2	60·2	80·3	100·4	120·5	140·5	160·6	180·7
2⅞	21·9	43·9	65·8	87·8	109·7	131·7	153·6	175·6	197·5
3	23·9	47·8	71·7	95·6	119·4	143·3	167·2	191 1	215·0
3⅛	25·9	51·9	77·8	103·7	129·6	155·6	181·5	207·4	233·3
3¼	28·0	56·1	84·1	112·2	140·2	168·2	196·3	224·3	253·4
3⅜	30·2	60·5	90·7	121·0	151·2	181·4	211·7	241·9	272·2
3½	32·5	65·0	97·5	1[illegible]0·0	162·6	195·1	227·6	260·1	292·6
3⅝	34·9	69·8	104·7	139·5	174·4	209·3	244·2	279·1	314·0
3¾	37·3	74·7	112·0	149·3	186·7	224·0	261·3	298·7	336·0
3⅞	39·9	79·7	[illegible]	159·5	199·3	239·2	279·0	318·9	358·8

TABLE II.—ROUND IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$\frac{1}{4}$	1·7	1·8	2·0	2·1	2·3	2·5	2·6	2·8	3·0
$\frac{3}{8}$	3·7	4·1	4·5	4·8	5·2	5·6	6·0	6·3	6·7
$\frac{1}{2}$	6·6	7·3	8·0	8·6	9·3	9·9	10·6	11·3	11·9
$\frac{5}{8}$	10·4	11·5	12·5	13·6	14·6	15·6	16·7	17·3	18·8
$\frac{3}{4}$	14·9	16·4	17·9	19·4	20·9	22·4	23·9	25·4	26·9
$\frac{7}{8}$	20·3	22·4	24·4	26·4	28·4	30·5	32·5	34·5	36·6
1	26·5	29·2	31·8	34·5	37·2	39·8	42·5	45·1	47·8
$1\frac{1}{8}$	33·6	37·0	40·3	43·7	47·0	50·4	53·8	57·1	60·5
$1\frac{1}{4}$	41·7	45·9	50·1	54·2	58·4	62·6	66·8	70·9	75·1
$1\frac{3}{8}$	50·2	55·2	60·2	65·2	70·3	75·3	80·3	85·3	90·3
$1\frac{1}{2}$	59·7	65·7	71·7	77·6	83·6	89·6	95·6	101·5	107·5
$1\frac{5}{8}$	70·1	77·1	84·1	91·1	98·1	105·2	112·2	119·2	126·2
$1\frac{3}{4}$	81·3	89·4	97·5	105·7	113·8	121·9	130·0	138·2	146·3
$1\frac{7}{8}$	93·3	102·7	112·0	121·3	130·7	140·0	149·3	158·7	168·0
2	106·2	116·8	127·4	138·0	148·6	159·2	169·9	180·5	192·1
$2\frac{1}{8}$	119·9	131·9	143·9	155·8	167·8	179·8	181·8	193·8	205·8
$2\frac{1}{4}$	134·4	147·8	161·3	174·7	188·2	201·6	215·0	228·5	241·9
$2\frac{3}{8}$	149·8	164·7	179·7	194·7	209·7	224·6	239·6	254·6	269·6
$2\frac{1}{2}$	166·9	183·6	200·3	216·9	233·6	250·3	267·0	283·7	300·4
$2\frac{5}{8}$	182·9	201·2	219·5	237·8	256·1	274·4	292·7	311·0	329·3
$2\frac{3}{4}$	200·8	220·8	240·9	261·2	281·1	301·1	321·2	341·3	361·4
$2\frac{7}{8}$	219·4	241·4	263·4	285·3	307·2	329·2	351·1	373·0	395·0
3	238·9	262·8	286·7	310·5	334·4	358·3	382·2	406·1	430·0
$3\frac{1}{8}$	259·3	285·2	311·1	337·0	363·0	388·9	414·8	440·7	466·7
$3\frac{1}{4}$	280·4	308·4	336·5	364·5	392·6	420·6	448·6	476·7	504·7
$3\frac{3}{8}$	302·4	332·6	362·9	393·1	423·4	453·6	483·8	514·1	544·3
$3\frac{1}{2}$	325·1	357·6	390·1	422·7	455·2	487·7	520·2	552·7	585·2
$3\frac{5}{8}$	348·9	383·7	418·6	453·5	488·4	523·3	558·2	593·1	627·9
$3\frac{3}{4}$	373·3	410·7	448·0	485·3	522·6	560·0	597·3	634·6	672·0
$3\frac{7}{8}$	398·6	438·5	478·4	518·2	558·1	598·0	637·8	677·7	717·6

TABLE II.—ROUND IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	42·5	84·9	127·4	169·9	212·3	254·8	297·2	339·7	382·2
4⅛	45·2	90·3	135·5	180·7	225·9	271·0	316·2	361·4	406·6
4¼	48·0	95·9	143·9	191·8	239·8	287·7	335·7	383·6	431·6
4⅜	50·8	101·6	152·4	203·3	254·1	304·9	355·7	406·5	457·3
4½	53·8	107·5	161·3	215·0	268·8	322·6	376·3	430·1	483·8
4⅝	56·8	113·6	170·4	227·2	283·9	340·7	397·5	454·3	511·1
4¾	60·0	119·8	179·7	239·6	299·5	359·4	419·3	479·2	539·1
4⅞	63·1	126·2	189·3	252·4	315·5	378·6	441·7	504·8	567·8
5	66·8	133·5	200·3	267·0	333·8	400·5	467·3	534·0	600·8
5⅛	69·7	139·5	209·2	278·9	348·7	418·4	488·1	557·8	627·6
5¼	73·2	146·3	219·5	292·7	365·9	439·0	512·2	585·4	658·5
5⅜	76·7	153·4	230·1	306·8	383·5	460·2	536·9	613·6	690 3
5½	80·3	160·6	240·9	321·2	401·5	481·8	562·1	642·4	722·7
5⅝	84·0	168·0	252·0	336·0	420·0	504·0	588·0	672·0	756·0
5¾	87·8	175·6	263·3	351·1	438·9	526·7	614·4	702·2	790·0
5⅞	91·6	183·3	274·9	366·5	458·2	549·8	641·4	733·1	824·7
6	95·6	191·1	286·7	382·2	477·8	573·3	668·9	764·4	860·0
6¼	103·7	207·4	311·1	414·8	518·5	622·2	725·9	829·6	933·3
6½	112·2	224·3	336·5	448·6	560·8	673·0	785·1	897·3	1009·4
6¾	121·0	241·9	362·9	483·8	604·8	725·8	846·7	967·6	1088·6
7	130·0	260·1	390·1	520·2	650·2	780·3	910·3	1040·4	1170·4
7¼	139·5	279·1	418·6	558·2	697·7	837·3	976·8	1116·4	1255·9
7½	149·3	298·7	448·0	597·3	741·6	896·0	1045·3	1194·6	1344·0
7¾	159·5	318·9	478·4	637·8	797·3	956·7	1116·2	1275·6	1435·1
8	169·9	339·7	509·6	679·4	849·3	1019·1	1189·0	1358·8	1528·7
8¼	180·7	361·4	542·1	722·8	903·5	1084·2	1264·9	1445·6	1626·3
8½	191·8	383·6	595·4	767·2	959·0	1150·8	1342·6	1534·5	1726·3
8¾	203·3	406·5	609·8	813·0	1016·3	1219·6	1422·8	1626·1	1829·3
9	215·0	430·1	645·1	860·2	1075·2	1290·2	1505·3	1720·3	1935·4

TABLE II.—ROUND IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4	424·6	467·1	509·6	552·0	594·5	637·0	676·4	721·9	764·4
4⅛	451·7	496·9	542·1	587·3	632·4	677·6	722·8	761·0	813·1
4¼	479·5	527·5	575·4	623·4	671·3	719·3	767·2	815·2	863·1
4⅜	508·2	559·0	609·8	660·6	711·4	762·2	813·0	863·9	914·7
4½	537·6	591·4	645·1	698·9	752·6	806·4	860·2	913·9	967·7
4⅝	567·9	624·7	681·5	738·2	795·0	851·8	908·6	965·4	1022·2
4¾	599·0	658·9	718·8	778·7	838·6	898·5	958·4	1018·3	1078·2
4⅞	630·9	694·0	757·1	820·2	883·3	946·4	1009·5	1072·6	1135·7
5	667·5	734·3	801·0	867·8	934·5	1001·3	1068·0	1134·8	1201·5
5⅛	697·3	767·0	836·8	906·5	976·2	1046·0	1115·7	1185·4	1255·2
5¼	731·7	804·9	878·1	951·2	1024·4	1097·6	1170·8	1243·9	1317·1
5⅜	767·0	813·7	920·4	997·1	1073·8	1150·5	1227·2	1303·9	1380·6
5½	803·0	883·3	963·6	1044·0	1124·3	1204·6	1284·9	1365·2	1445·5
5⅝	840·0	924·0	1008·0	1092·0	1176·0	1260·0	1344·0	1428·0	1512·0
5¾	877·8	965·5	1053·3	1141·1	1228·9	1316·6	1404·4	1492·2	1580·0
5⅞	916·3	1008·0	1099·6	1191·2	1282·9	1374·5	1466·1	1557·8	1649·4
6	955·5	1051·1	1146·6	1242·2	1337·7	1433·3	1528·8	1624·4	1719·9
6¼	1037·0	1140·7	1244·4	1348·2	1451·9	1555·6	1659·3	1763·0	1866·7
6½	1121·6	1233·8	1345·9	1458·1	1570·2	1682·4	1794·6	1906·7	2018·9
6¾	1209·6	1330·6	1451·5	1572·5	1693·4	1814·4	1935·4	2056·3	2177·3
7	1300·5	1430·5	1560·6	1690·6	1820·7	1950·7	2088·8	2210·8	2340·9
7¼	1395·4	1535·0	1674·5	1814·1	1953·6	2093·2	2232·7	2372·2	2511·8
7½	1493·3	1642·6	1791·9	1941·3	2090·6	2239·9	2389·2	2538·6	2687·9
7¾	1594·6	1754·0	1913·5	2072·9	2232·4	2391·8	2551·3	2710·8	2870·2
8	1698·6	1868·4	2038·3	2208·1	2378·0	2547·8	2717·7	2887·6	3057·4
8¼	1809·0	1987·7	2168·4	2349·0	2529·7	2740·4	2891·1	3071·8	3252·5
8½	1918·1	2109·9	2301·7	2493·5	2685·3	2879·1	3068·9	3260·7	3452·5
8¾	2032·6	2235·9	2439·1	2642·4	2845·6	3048·9	3252·2	3455·4	3658·7
9	2150·4	2365·4	2580·5	2795·5	3010 6	3225·6	3440·6	3655·7	3870·7

TABLE II.—ROUND IRON.

size.	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
9¼	227·2	454·3	681·5	908·6	1135·8	1362·9	1590·1	1817·2	2044·4
9½	239·6	479·2	718·8	958·4	1198·0	1437·6	1677·2	1916·8	2156·4
9¾	252·4	505·8	757·1	1009·5	1261·9	1514·3	1766·6	2019·0	2291·4
10	266·3	532·6	798·9	1065·2	1331·4	1597·7	1864·0	2130·3	2396·6
10¼	278·9	557·8	836·8	1115·7	1394·6	1673·5	1952·5	2231·4	2510·3
10½	292·7	585·4	878·1	1170·8	1463·4	1756·1	2048·8	2341·5	2634·2
10¾	306·8	603·6	920·4	1227·2	1534·0	1840·8	2147·6	2454·4	2761·2
11	321·2	642·4	963·6	1284·9	1606·1	1927·3	2248·5	2569·7	2890·9
11¼	336·0	672·0	1008·0	1344·0	1680·0	2016·0	2352·0	2688·0	3024·0
11½	351·1	702·2	1053·3	1404·4	1755·5	2106·6	2457·7	2808·8	3159·9
11¾	366·5	733·1	1099·6	1466·1	1832·7	2199·2	2565·8	2932·3	3298·8
12	382·2	764·4	1146·6	1528·8	1911·0	2293·2	2675·5	3057·7	3439·9

TABLE II.—ROUND IRON.

size.	10 ft.	11 ft.	12 ft.	13 ft.	14 ft.	15 ft.	16 ft.	17 ft.	18 ft.
inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
$9\frac{1}{4}$	2271·5	2498·7	2725·8	2953·0	3180·1	3407·3	3634·4	3861·6	4088·7
$9\frac{1}{2}$	2396·0	2635·6	2875·2	3114·8	3354·4	3594·0	3833·6	4073·2	4312·8
$9\frac{3}{4}$	2523·8	2776·1	3028·5	3280·9	3533·3	3785·6	4038·0	4290·4	4542·8
10	2662·9	2929·2	3195·5	3461·7	3728·0	3994·3	4260·6	4526·9	4793·2
$10\frac{1}{4}$	2789·2	3068·2	3347·1	3626·0	3904·9	4183·9	4462·8	4741·7	5020·6
$10\frac{1}{2}$	2926·9	3219·6	3512·3	3804·9	4097·6	4390·3	4683·0	4975·7	5268·4
$10\frac{3}{4}$	3068·0	3374·8	3681·6	3988·4	4295·2	4602·0	4908·8	5215·6	5522·4
11	3212·2	3533·4	3854·6	4175·8	4497·0	4818·2	5139·5	5460·7	5781·9
$11\frac{1}{4}$	3360·0	3696·0	4032·0	4368·1	4704·1	5040·1	5376·1	5712·1	6048·1
$11\frac{1}{2}$	3511·0	3862·1	4213·2	4564·4	4915·5	5266·6	5619·7	5968·8	6319·9
$11\frac{3}{4}$	3665·4	4031·9	4398·4	4765·0	5131·5	5498·0	5864·6	6231·1	6597·6
12	3822·1	4204·3	4586·5	4968·7	5350·9	5733·1	6115·3	6497·5	6879·7

TABLE III.—FLAT IRON.

Th'k.	Wid.	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft	8 ft	9 ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	1	0·8	1·7	2·5	3·4	4·2	5·1	5·9	6·8	7 6
¼	1¼	1·1	2·1	3·2	4·2	5·3	6·3	7·4	8·4	9·5
¼	1½	1·3	2·5	3·8	5·1	6·3	7·6	8·9	10·1	11·4
¼	1¾	1·5	3·0	4·4	5·9	7·4	8·9	10·4	11·8	13·3
¼	2	1·7	3·4	5·1	6·8	8·5	10·1	11·8	13·5	15·2
¼	2¼	1·9	3·8	5·7	7·6	9·5	11·4	13·3	15·2	17·1
¼	2½	2·1	4·2	6·3	8·4	10·6	12·7	14·8	16·9	19 0
¼	2¾	2·3	4·6	7·0	9·3	11·6	13·9	16·3	18·6	20 9
¼	3	2·5	5·1	7·6	10·1	12·7	15·2	17·7	20·3	22 8
¼	3¼	2·7	5·5	8·2	11·0	13·7	16·5	19·2	22·0	24·7
¼	3½	3·0	5·9	8·9	11·8	14·8	17·7	20·7	23·7	26·6
¼	3¾	3·2	6·3	9·5	12·7	15·8	19·0	22·2	25·4	28·5
¼	4	3·4	6·8	10·1	13·5	16·9	20·3	23·7	27·0	30·4
¼	4¼	3·6	7·2	10·8	14·4	18·0	21·5	25·1	28·7	32·3
¼	4½	3·8	7·6	11·4	15·2	19·0	22·8	26·6	30·4	34·2
¼	4¾	4·0	8·0	12·0	16·1	20·1	24·1	28·1	32·1	36·1
¼	5	4·2	8·4	12·7	16·9	21·1	25·3	29·6	33·8	38·0
¼	5¼	4·4	8·9	13·3	17·7	22·2	26·6	31·1	35·5	39·9
¼	5½	4·6	9·3	13·9	18·6	23·2	27·9	32·5	37·2	41·8
¼	5¾	4·9	9·7	14 6	19·4	24·3	29·2	34·0	38·9	43·7
¼	6	5·1	10·1	15·2	20·3	25·3	30·4	35·5	40·6	45·6
⅜	1	1·3	2·5	3·8	5·1	6·3	7·6	8·9	10·1	11·4
⅜	1¼	1·6	3·2	4·8	6·3	7·9	9·5	11·1	12·7	14·3
⅜	1½	1·9	3·8	5·7	7·6	9·5	11·4	13·3	15·2	17·1
⅜	1¾	2·2	4·4	6·7	8·9	11·1	13·3	15·5	17·7	20·0
⅜	2	2·5	5·1	7·6	10·1	12·7	15·2	17·7	20·3	22·8
⅜	2¼	2·9	5·7	8·3	11·4	14·3	17·1	20·0	22·8	25·7
⅜	2½	3·2	6·3	9·5	12·7	15·8	19·0	22·2	25·4	28·5

TABLE III.—FLAT IRON.

Th'k.	Wid.	10ft	11ft	12ft	13ft	14ft	15ft	16ft	17ft	18ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
¼	1	8·5	9·3	10·1	11·0	11·8	12·7	13·5	14·4	15·2
¼	1¼	10·6	11·6	12·7	13·7	14·8	15·8	16·9	17·9	19·0
¼	1½	12·7	13·9	15·2	16·5	17·7	19·0	20·3	21·5	22·8
¼	1¾	14·8	16·3	17·7	19·2	20·7	22·2	23·7	25·1	26·6
¼	2	16·9	18·6	20·3	22·0	23·7	25·4	27·0	28·7	30·4
¼	2¼	19·0	20·9	22·8	24·7	26·6	28·5	30·4	32·3	34·2
¼	2½	21·1	23·2	25·3	27·5	29·6	31·7	33·8	35·9	38·0
¼	2¾	23·2	25·6	27·9	30·2	32·5	34·9	37·2	39·5	41·8
¼	3	25·3	27·9	30·4	33·0	35·5	38·0	40·6	43·1	45·6
¼	3¼	27·5	30·2	33·0	35·7	38·5	41·3	43·9	46·7	49·4
¼	3½	29·6	32·5	35·5	38·5	41·4	44·4	47·3	50·3	53·2
¼	3¾	31·7	34·9	38·0	41·2	44·4	47·5	50 7	53·9	57·0
¼	4	33·8	37·2	40·6	43·9	47·3	50·7	54·1	57·5	60·8
¼	4¼	35·9	39·5	43·1	46·7	50·3	53·9	57·5	61·0	64·6
¼	4½	38·0	41·8	45·6	49·4	53·2	57·0	60·8	64·6	68·4
¼	4¾	40·1	44·1	48·2	52·2	56·2	60·2	64·2	68·2	72·2
¼	5	42·2	46·5	50·7	54·9	59·1	63·4	65·6	71·8	76·0
¼	5¼	44·4	48·8	53·2	57·7	62·1	66·5	71·0	75·4	79·9
¼	5½	46·5	51·1	55·8	60·4	65·1	69·7	74·4	79·0	83·6
¼	5¾	48·6	53·4	58·3	63·2	68·0	72·9	77·7	82·6	87·5
¼	6	50·7	55·8	60·8	65·9	70·9	76·0	81·1	86·2	91·2
⅜	1	12·7	13·9	15·2	16·5	17·7	19·0	20·3	21·5	22·8
⅜	1¼	15·8	17·4	19·0	20·6	22·2	23·8	25·3	28·9	28·5
⅜	1½	19·0	20·9	22·8	24·7	26·6	28·5	30·4	32·3	34·2
⅜	1¾	22·2	24·4	26·6	28·8	31·1	33·3	35·5	37·7	39·9
⅜	2	25·3	27·9	30·4	33·0	35·5	38·0	40·6	43·1	45·6
⅜	2¼	28·5	31·4	34·2	37·1	39·9	42·8	45·6	48·5	51·3
⅜	2½	31·7	34·9	38·0	41·2	44·4	47·5	50·7	53·9	57·0

TABLE III.—FLAT IRON.

Th'k.	Wid.	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft	8 ft	9 ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
⅜	2¾	3·5	7·0	10·5	13·9	17·4	20·9	24·4	27·9	31·4
⅜	3	3·8	7·6	11·4	15·2	19·0	22·8	26·6	30·4	34·2
⅜	3¼	4·1	8·2	12·4	16·5	20·6	24·7	28·8	33·0	37·1
⅜	3½	4·4	8·9	13·3	17·7	22·2	26·6	31·1	35·5	39·9
⅜	3¾	4·8	9·5	14·3	19·0	23·8	28·5	33·3	38·0	42·8
⅜	4	5·1	10·1	15·2	20·3	25·3	30·4	35·5	40·6	45·6
⅜	4¼	5·4	10·8	16·1	21·5	26·9	32·3	37·7	43·1	48·5
⅜	4½	5·7	11·4	17·1	22·8	28·5	34·2	39·9	45·6	51·3
⅜	4¾	6·0	12·0	18·1	24·1	30·1	36·1	42·1	48·2	54·2
⅜	5	6·3	12·7	19·0	25·3	31·7	38·0	44·4	50·7	57·0
⅜	5¼	6·7	13·3	20·0	26·6	33·3	39·9	46·6	53·2	59·9
⅜	5½	7·0	13·9	20·9	27·9	34·9	41·8	48·8	55·8	62·7
⅜	5¾	7·3	14·6	21·9	29·2	36·4	43·7	51·0	58·3	65·6
⅜	6	7·6	15·2	22·8	30·4	38·0	45·6	53·2	60·8	68·4
½	1	1·7	3·4	5·1	6·8	8·5	10·1	11·8	13·5	15·2
½	1¼	2·1	4·2	6·3	8·4	10·6	12·7	14·8	16·9	19·0
½	1½	2·5	5·1	7·6	10·1	12·7	15·2	17·7	20·3	22·8
½	1¾	3·0	5·9	8·9	11·8	14·8	17·7	20·7	23·7	26·6
½	2	3·4	6·8	10·1	13·5	16·9	20·3	23·7	27·0	30·4
½	2¼	3·8	7·6	11·4	15·2	19·0	22·8	26·6	30·4	34·2
½	2½	4·2	8·4	12·7	16·9	21·1	25·3	29·6	33·8	38·0
½	2¾	4·6	9·3	13·9	18·6	23·2	27·9	32·5	37·2	41·8
½	3	5·1	10·1	15·2	20·3	25·3	30·4	35·5	40·6	45·6
½	3¼	5·5	11·0	16·5	22·0	27·5	32·9	38·4	43·9	49·4
½	3½	5·9	11·8	17·7	23·7	29·6	35·5	41·4	47·3	53·2
½	3¾	6·3	12·7	19·0	25·3	31·7	38·0	44·4	50·7	57·0
½	4	6·8	13·5	20·3	27·0	33·8	40·6	47·3	54·1	60·8

TABLE III.—FLAT IRON.

Th'k.	Wid.	10ft	11ft	12ft	13ft	14ft	15ft	16ft	17ft	18ft
inch	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
⅜	2¾	34·9	36·3	41·8	45·3	48·8	52·3	55·8	59·3	62·7
⅜	3	38·0	41·8	45·6	49·4	53·2	57·0	60·8	64·6	68·4
⅜	3¼	41·2	45·3	49·4	53·6	57·7	61·8	65·9	70·0	74·2
⅜	3½	44·4	48·8	53·2	57·7	62·1	66·5	71·0	75·4	79·9
⅜	3¾	47·5	52·3	57·0	61·8	66·5	71·3	76·0	80·8	85·5
⅜	4	50·7	55·8	60·8	65·9	70·9	76·0	81·1	86·2	91·2
⅜	4¼	53·9	59·3	64·7	70·0	75·4	80·8	86·2	91·6	97·0
⅜	4½	57·0	62·7	68·4	74·2	79·9	85·6	91·3	97·0	102·7
⅜	4¾	60·2	66·2	72·2	78·3	84·3	90·3	96·3	102·3	108·4
⅜	5	63·3	69·7	76·0	82·4	88·7	95·0	101·4	107·7	114·0
⅜	5¼	66·5	73·2	79·8	86·5	93·1	99·8	106·5	113·1	119·8
⅜	5½	69·7	76·7	83·7	90·6	97·6	104·5	111·5	118·5	125·5
⅜	5¾	72·9	80·2	87·5	94·7	102·0	109·3	116·6	123·9	131·2
⅜	6	76·0	83·6	91·2	98·9	106·5	114·1	121·7	129·3	136·9
½	1	16·9	18·6	20·3	22·0	23·7	25·4	27·0	28·7	30·4
½	1¼	21·1	23·2	25·3	27·5	29·6	31·7	33·8	35·9	38·0
½	1½	25·3	27·9	30·4	33·0	35·5	38·0	40·6	43·1	45·6
½	1¾	29·6	32·5	35·5	38·5	41·4	44·4	47·3	50·3	53·2
½	2	33·8	37·2	40·6	43·9	47·3	50·7	54·1	57·5	60·8
½	2¼	38·0	41·8	45·6	49·4	53·2	57·0	60·8	64·6	68·4
½	2½	42·2	46·5	50·7	54·9	59·1	63·4	65·6	71·8	76·0
½	2¾	46·5	51·1	55·8	60·4	65·1	69·7	74·4	79·0	83·6
½	3	50·7	55·8	60·8	65·9	70·9	76·0	81·1	86·2	91·2
½	3¼	54·9	60·4	65·9	71·4	76·9	82·4	87·9	93·3	98·8
½	3½	59·2	65·1	71·0	76·9	82·8	88·7	94·6	100·6	106·5
½	3¾	63·3	69·7	76·0	82·4	88·7	95·0	101·4	107·7	114·0
½	4	67·6	74·4	84·1	87·9	94·6	101·4	108·2	114·9	121·7

'ABLE III.—FLAT IRON

Th'k.	W.d	1 ft	2 ft	3 ft	ft 5	5 ft	6 ft	7 ft	8 ft	9 ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
½	4¼	7·2	14·4	21·5	28·7	35·9	43·1	50·3	57·4	64·6
½	4½	7·6	15·2	22·8	30·4	38·0	45·6	53·2	60·8	68·4
½	4¾	8·0	16·1	24·1	32·1	40·1	48·2	56·2	64·2	72·2
½	5	8·4	16·9	25·3	33·8	42·2	50·7	59·1	67 6	76·0
½	5¼	8·9	17·7	26·6	35·5	44·4	53·2	62·1	71·0	79·9
½	5½	9·3	18·6	27·9	37·2	46·5	55·8	65·1	74·4	83·7
½	5¾	9·7	19·4	29·2	38·9	48·6	58·3	68·0	77·7	87·5
½	6	10·1	20·3	30·4	40·6	50·7	60.8	70·9	81·1	91·2
⅝	1	2·1	4·2	6·3	8·4	10·6	12·7	14·8	16·9	19·0
⅝	1¼	2·6	5·3	7·9	10·6	13·2	15·8	18·5	21·1	23·8
⅝	1½	3·2	6·3	9·5	12·7	15·8	19·0	22·2	25·4	28·5
⅝	1¾	3·7	7·4	11·1	14·8	18·5	22·2	25·9	29·6	33·3
⅝	2	4·2	8·4	12·7	16·9	21·1	25·3	29·9	33·8	38·0
⅝	2¼	4·8	9·5	14·3	19·0	23·8	28·5	33·3	38·0	42·8
⅝	2½	5·3	10·6	15·8	21·1	26·4	31·7	37·0	42·2	47·5
⅝	2¾	5·8	11·6	17·4	23·2	29·0	34·8	40·7	46·5	52·3
⅝	3	6·3	12·7	19·0	25·3	31·7	38·0	44·4	50·7	57·6
⅝	3¼	6·9	13·7	20·6	27·5	34·3	41·2	48·1	54·9	61·8
⅝	3½	7·4	14·8	22·2	29·6	37·0	44·4	51·8	59·2	66·5
⅝	3¾	7·9	15·8	23·8	31·7	39·6	47·5	55·5	63·4	71·3
⅝	4	8·4	16·9	25·3	33·8	42·2	50·7	59·1	67·6	76·0
⅝	4¼	9·0	18·0	26·9	35·9	44·9	53·9	62·9	71·8	80·8
⅝	4½	9·5	19·0	28·5	38·0	47·5	57·0	66·5	76·1	85·6
⅝	4¾	10·0	20·1	30·1	40·1	50·2	60·2	70·2	80·3	90·3
⅝	5	10·6	21·1	31·7	42·3	52·8	63·4	73·9	84·5	95·1
⅝	5¼	11·1	22·2	33·3	44·4	55·5	66·5	77·6	88·7	99·8
⅝	5½	11·6	23·2	34·9	46·5	58·1	69·7	81·3	92·9	104·6
⅝	5¾	12·1	24·3	36·4	48·6	60·7	72·9	85·0	97·2	109·3

TABLE III.—FLAT IRON.

Th'k.	Wid.	10ft	11ft	12ft	13ft	14ft	15ft	16ft	17ft	18ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
½	4¼	71·8	79·0	86·2	93·4	100·5	107·7	114·9	122·1	129·3
½	4½	76·0	83·6	91·2	98·9	106·5	114·1	121·7	129·3	136·9
½	4¾	80·3	88·3	96·3	104·3	112·4	120·4	128·4	136·4	144·5
½	5	84·5	92·9	101·4	109·8	118·3	126·7	135·2	143·6	152·1
½	5¼	88·7	97·6	106·5	115·4	124·2	133·1	142·0	150·8	159·7
½	5½	93·0	102·2	111·5	120·8	130·1	139·4	148·7	158·0	167·3
½	5¾	97·2	106·9	116·6	126·3	136·0	145.8	155·5	165·2	174·9
½	6	101·4	111·5	121·7	131·8	141·9	152·1	162·2	172·4	182·5
⅝	1	21·1	23·2	25·3	27·5	29·6	31·7	33·8	35·9	38·0
⅝	1¼	26·4	29·0	31·7	34·3	37·0	39·6	42·2	44·9	47·5
⅝	1½	31·7	34·8	38·0	41·2	44·4	47·5	50·7	53·9	57·0
⅝	1¾	37·0	40·7	44·4	48·1	51·8	55·5	59·2	62·8	66·5
⅝	2	42·2	46·5	50·7	54·9	60·1	63·4	67·6	71·8	76·0
⅝	2¼	47·5	52·3	57·0	51·8	66·5	71·3	76·0	80·8	85·5
⅝	2½	52·8	58·1	63·4	68·6	73·9	79·2	84·5	89·8	95·0
⅝	2¾	58·1	63·9	69·7	75·5	81·3	87·1	92·9	98·7	104·5
⅝	3	63·3	69·7	76·0	82·4	88·7	95·0	101·4	107·7	114·0
⅝	3¼	68·7	75·5	82·4	89·3	96·1	103·0	109·9	116·7	123·6
⅝	3½	73·9	81·3	88·7	96·1	103·5	110·9	118·3	125·7	133·1
⅝	3¾	79·2	87·1	95·1	103·0	110·9	118·8	126·8	134·7	142·6
⅝	4	84·5	92·9	101·4	109·8	118·3	126·7	135·2	143·6	152·1
⅝	4¼	89·8	98·8	107·8	116·7	125·7	134·7	143·7	152·6	161·6
⅝	4½	95·1	104·6	114·1	123·6	133·1	142·6	152·1	161·6	171·1
⅝	4¾	100·3	110·4	120·4	130·4	140·5	150·5	160·5	170·6	180·6
⅝	5	105·6	116·2	126·8	137·3	147·9	158·4	169·0	179·6	190·1
⅝	5¼	110·9	122·0	133·1	144·2	155·3	166·4	177·5	188·5	199·6
⅝	5½	116·2	127·8	139·4	151·0	162·6	174·3	185·9	197·5	209·1
⅝	5¾	121·5	133·6	145·7	157·9	170·0	182·2	194·3	206·5	218·6

TABLE III.—FLAT IRON

Thk.	Wid.	1 ft	2 ft	3 ft	4 ft	5 ft	6 ft	7 ft	8 ft	9 ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5/8	6	12·7	25·3	38·0	50·7	63·4	76·0	88·7	101·4	114·1
3/4	1	2·5	5·1	7·6	10·1	12·7	15·2	17·7	20·3	22·8
3/4	1¼	3·2	6·3	9·5	12·7	15·8	19·0	22·2	25·4	28·5
3/4	1½	3·8	7·6	11·4	15·2	19·0	22·8	26 6	30·4	24·2
3/4	1¾	4·4	8·9	13·3	17·7	22·2	26·6	31·1	35·5	39·9
3/4	2	5·1	10·1	15·2	20·3	25·3	30·4	35·5	40·6	45·6
3/4	2¼	5·7	11·4	17·1	22·8	28·5	34·2	39·9	45·6	51·3
3/4	2½	6·3	12·7	19·0	25·3	31·7	38·0	44·4	50·7	57 0
3/4	2¾	7·0	13·9	20·9	27·9	34·9	41·8	48·8	55·8	62·7
3/4	3	7·6	15·2	22·8	30·4	38·0	45·6	53·2	60·9	68·4
3/4	3¼	8·2	16·5	24·7	33·0	41·2	49·4	57·7	65·9	74·2
3/4	3½	8·9	17·7	26·6	35·5	44·4	53·2	62·1	71·0	79·9
3/4	3¾	9·5	19·0	28·5	38·0	47·5	57·0	66·5	76·1	85·6
3/4	4	10·1	20·3	30·4	40·6	50·7	60·8	70·9	81·1	91·2
3/4	4¼	10·8	21·5	32·3	43·1	53·9	64·6	75·4	86·2	97·0
3/4	4½	11·4	22·8	34·2	45·6	57·0	68·4	79·9	91·3	102·7
3/4	4¾	12·0	24·1	36·1	48·2	60·2	72·2	84·3	96·3	108·4
3/4	5	12·7	25·3	38·0	50·7	63·4	76·0	88·7	101·4	114·0
3/4	5¼	13·3	26·6	39·9	53·2	66·5	79·8	93·1	106·5	119·8
3/4	5½	13·9	27·9	41·8	55·8	69·7	83·7	97·6	111·5	125·5
3/4	5¾	14·6	29·1	43·7	58·3	72·9	87·4	102·0	116·6	131·2
3/4	6	15·2	30·4	45 6	60·8	76·0	91·2	106·5	121·7	136·9
1	1½	5·1	10·1	15·2	20·3	25·3	30·4	35·5	40·6	45·6
1	2	6·8	13·5	20·3	27·0	33·8	40·6	47·8	54·1	60·8
1	3	10·1	20·3	30·4	40·6	50·7	60·8	70·9	81·1	91·2
1	4	13·5	27·0	40·6	54·1	67·6	81·1	94·6	108·1	121·7
1	5	16·9	33·8	50·7	67·6	84·5	101·4	118·3	135·2	152·1
1	6	20·3	40·6	60·8	81·1	101·4	121·7	141·9	162·2	182·5

TABLE III.—FLAT IRON.

Th'k.	Wid.	10ft	11ft	12ft	13ft	14ft	15ft	16ft	17ft	18ft
inch.	inch.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
⅝	6	126·7	139·4	152·1	164·8	177·4	190·1	202·8	215·4	228·1
¾	1	25·3	27·9	30·4	33·0	35·5	38·0	40·6	43·1	45·6
¾	1¼	31·7	34·9	38·0	41·2	44·4	47·5	50·7	53·9	57·0
¾	1½	38·0	41·8	45·6	59·4	53·2	57·0	60·8	64·6	68·4
¾	1¾	44·4	48·8	53·2	57·7	62·1	66·5	71·0	75·4	79·9
¾	2	50·7	55·8	60·8	65·9	70·9	76·0	81·1	86·2	91·2
¾	2¼	57·0	62·7	68·4	74·2	79·9	85·5	91·3	97·0	102·7
¾	2½	63·3	69·7	76·0	82·4	88·7	95·0	101·4	107·7	114·0
¾	2¾	69·7	76·7	83·7	90·6	97·6	104·5	111·5	118·5	125·5
¾	3	76·0	83·6	91·2	98·9	106·5	114·1	121·7	129·3	136·9
¾	3¼	82·4	90·6	98·9	107·1	115·3	123·6	131·8	140·0	148·3
¾	3½	88·7	97·6	106·5	115·4	124·2	133·1	142·0	150·8	159·7
¾	3¾	95·1	104·6	114·1	123·6	133·1	142·6	152·1	161·6	171·1
¾	4	101·4	111·5	121·7	131·8	141·9	152·1	162·2	172·4	182·5
¾	4¼	107·7	118·5	129·3	140·1	150·8	161·6	172·4	183·2	193·9
¾	4½	114·1	125·5	136·9	148·3	159·7	171·1	182·5	193·9	205·3
¾	4¾	120·4	132·4	144·5	156·5	168·6	180·6	192·6	204·7	216·7
¾	5	126·7	139·4	152·1	164·8	177·4	190·1	202·8	215·4	228·1
¾	5¼	133·1	146·4	159·7	173·0	186·3	199·6	212·9	226·2	239·5
¾	5½	139·4	153·3	167·3	181·2	195·2	209·2	223·1	237·0	250·9
¾	5¾	145·7	160·3	174·9	189·5	204·0	218·6	233·2	247·8	262·3
¾	6	152·1	167·3	182·5	197·7	212·9	228·1	243·3	258·5	273·7
1	1½	50·7	55·8	60·8	65·9	70·9	76·0	81·1	86·2	91·2
1	2	67·6	74·4	81·1	87·9	94·6	101·4	108·1	114·9	121·7
1	3	101·4	111·5	121·7	131·7	141·9	152·1	162·2	172·4	182·5
1	4	135·2	148·7	162·2	175·7	189·3	202·8	216·7	229·8	243·3
1	5	169·0	185·9	202·8	219·7	236·6	253·5	270·4	287·3	304·2
1	6	202·8	223·1	243·3	263·6	283·9	304·2	324·4	344·7	365·0

The tables are all calculated to the nearest tenth of a pound. To the weights of bars of Wrought Iron, add $\frac{1}{160}$th part for bars of Soft Steel; and from the same weights subtract $\frac{1}{14}$th part for bars of Cast Iron.

Proportional Breadths for hexagonal or six-sided Nuts for Wrought-Iron Bolts.

Dia. of bolts.	Breadth of nuts.	Dia. of bolts.	Breadth of nuts
$\frac{3}{8}$	$\frac{3}{4}$ inch.	$1\frac{1}{8}$	$1\frac{15}{16}$ inch.
$\frac{1}{2}$	$\frac{7}{8}$ "	$1\frac{1}{4}$	$2\frac{3}{16}$ "
$\frac{5}{8}$	$1\frac{1}{8}$ "	$1\frac{3}{8}$	$2\frac{3}{8}$ "
$\frac{3}{4}$	$1\frac{5}{16}$ "	$1\frac{1}{2}$	$2\frac{9}{16}$ "
$\frac{7}{8}$	$1\frac{1}{2}$ "	$1\frac{5}{8}$	$2\frac{3}{4}$ "
1	$1\frac{3}{4}$ "	$1\frac{3}{4}$	3 "

Note.—The thickness of the nut is equal the bolt's diameter.

WEIGHT OF A SUPERFICIAL FOOT OF PLATE OR SHEET IRON, COPPER, AND BRASS, IN POUNDS.

Thickness in parts of an inch.	Iron.
$\frac{1}{32}$	1·25
$\frac{1}{16}$	2·5
$\frac{1}{8}$	5
$\frac{3}{16}$	7·5
$\frac{1}{4}$	10
$\frac{5}{16}$	12·5
$\frac{3}{8}$	15
$\frac{7}{16}$	17·5
$\frac{1}{2}$	20
$\frac{9}{16}$	22·5
$\frac{5}{8}$	25
$\frac{11}{16}$	27·5
$\frac{3}{4}$	30
$\frac{7}{8}$	35
1	40

Thickness by the wire gauge.

No.	Iron.	Copper.	Brass.
1	12·5	14·5	13·75
2	12	13·9	13·2
3	11	12·75	12·1
4	10	11·6	11
5	8·74	10·1	9·61
6	8·12	9·4	8·93
7	7·5	8·7	8·25
8	6·86	7·9	7·54
9	6·24	7·2	6·86
10	5·62	6·5	6·18
11	5	5·8	5·5
12	4·38	5·08	4·81
13	3·75	4·34	4·12
14	3·12	3·6	3·43
15	2·82	3·27	3·1

Thickness by the wire gauge.

No.	Iron.	Copper.	Brass.
16	2·5	2·9	2·75
17	2·18	2·52	2·4
18	1·86	2·15	2·04
19	1·7	1·97	1·87
20	1·54	1·78	1·69
21	1·4	1·62	1·54
22	1·25	1·45	1·37
23	1·12	1·3	1·23
24	1	1·16	1·1
25	·9	1·04	·99
26	·8	·92	·88
27	·72	·83	·79
28	·64	·74	·7
29	·56	·64	·61
30	·5	·58	·55

Note.—No. 1 wire gauge equal $\frac{5}{16}$ths of an inch.
" 4 " $\frac{1}{4}$ "
" 7 " $\frac{3}{16}$ "
" 11 " $\frac{1}{8}$ "
" 16 " $\frac{1}{16}$ "
" 22 " $\frac{1}{32}$ "

The great variety of thicknesses into which copper is manufactured, cause in trade the weight to be named whereby to determine the thickness required, the unit

being that of a common sheet, so designated, viz., 4 feet by 2 feet, in lbs., thus:—

A 70	lb. plate is			$\frac{3}{16}$ths	of an inch in thickness.					
" 46½	"	"	"	$\frac{1}{8}$	"	"	"	"	"	
" 23	"	"	"	$\frac{1}{16}$	"	"	"	"	"	
" 11½	"	"	"	$\frac{1}{32}$	"	"	"	"	"	
" 6	"	"	"	$\frac{1}{64}$	"	"	"	"	"	

The thickness of lead is also in common determined or understood by the weight; the unit being that of a square or superficial foot; thus:—

4	lbs. lead is			$\frac{1}{16}$th	of an inch in thickness.				
6	"	"	"	$\frac{1}{10}$	"	"	"	"	"
7½	"	"	"	$\frac{1}{8}$	"	"	"	"	"
11	"	"	"	$\frac{3}{16}$	"	"	"	"	"
15	"	"	"	$\frac{1}{4}$	"	"	"	"	"

COMPARATIVE WEIGHTS OF DIFFERENT BODIES.

Bar iron being 1,		Cast iron being 1,	
Cast iron	= ·95	Bar iron	= 1·07
Steel	= 1·02	Steel	= 1·08
Copper	= 1·16	Brass	= 1·16
Brass	= 1·09	Copper	= 1·21
Lead	= 1·48	Lead	= 1·56

1. Suppose I have an article of plate iron, the weight of which is 728 lbs., but want the same of copper, and of similar dimensions, what will be its weight?

$$728 \times 1{\cdot}16 = 844{\cdot}48 \text{ lbs.}$$

2. A model of dry pine, weighing 32½ lbs., and in which the iron for its construction forms no material portion of the weight, what may I anticipate its weight to be in cast iron?

$$32{\cdot}5 \times 16 = 520 \text{ lbs.}$$

Note.—It frequently occurs, in the formation or construction of models, that neither the quality nor condition of the timber can be properly estimated; and, in such cases, it may be a near enough approximation to reckon 15 lbs. of cast iron to each lb. of model.

TO ASCERTAIN THE WEIGHTS OF PIPES OF VARIOUS METALS, AND ANY DIAMETER REQUIRED.

Thickness in parts of an inch.	Wrought iron.	Copper.		Lead.	
$\frac{1}{32}$	·326	11½ lbs. plate,	·38	2 lbs. lead,	·483
$\frac{1}{16}$	·653	23½ " "	·76	4 " "	·967
$\frac{3}{32}$	·976	35 " "	1·14	5½ " "	1·45
$\frac{1}{8}$	1·3	46½ " "	1·52	8 " "	1·933
$\frac{5}{32}$	1·627	58 " "	1·9	9¼ " "	2·417
$\frac{3}{16}$	1·95	70 " "	2·28	11 " "	2·9
$\frac{7}{32}$	2·277	80½ " "	2·66	13 " "	3·383
$\frac{1}{4}$	2·6	93 " "	3·04	15 " "	3·867

Rule.—To the interior diameter of the pipe, in inches, add the thickness of the metal; multiply the sum by the decimal numbers opposite the required thickness, and under the metal's name; also, by the length of the pipe in feet; and the product is the weight of the pipe in lbs.

1. Required the weight of a copper pipe whose interior diameter is 7½ inches, its length 6¼ feet, and the metal ⅛ of an inch in thickness.

$$7{\cdot}5 + {\cdot}125 = 7{\cdot}625 \times 1{\cdot}52 \times 6{\cdot}25 = 72{\cdot}4 \text{ lbs.}$$

2. What is the weight of a leaden pipe 18½ feet in length, 3 inches interior diameter, and the metal ¼ of an inch in thickness?

$$3 + {\cdot}25 = 3{\cdot}25 \times 3{\cdot}867 \times 18{\cdot}5 = 232{\cdot}5 \text{ lbs.}$$

Note.—Weight of a cubic inch of

Lead	equal	·4103	lb.
Copper, sheet	"	·3225	"
Brass, do.	"	·3037	"
Iron, do.	"	·279	"
Iron, cast	"	·263	"
Tin, do.	"	·2636	"
Zinc, do.	"	·26	"
Water	"	·03617	"

WEIGHT OF CAST IRON BALLS.

Diameter in inches.	Weight in lbs.	Diameter in inches.	Weight in lbs.	Diameter in inches.	Weight in lbs.
2	1·10	6	29·72	10	137·71
$2\frac{1}{4}$	1·57	$6\frac{1}{4}$	33·62	$10\frac{1}{4}$	148·28
$2\frac{1}{2}$	2·15	$6\frac{1}{2}$	37·80	$10\frac{1}{2}$	159·40
$2\frac{3}{4}$	2·86	$6\frac{3}{4}$	42·35	$10\frac{3}{4}$	171·05
3	3·72	7	47·21	11	183·29
$3\frac{1}{4}$	4·71	$7\frac{1}{4}$	52·47	$11\frac{1}{4}$	196·10
$3\frac{1}{2}$	5·80	$7\frac{1}{2}$	58·06	$11\frac{1}{2}$	209·43
$3\frac{3}{4}$	7·26	$7\frac{3}{4}$	64·09	$11\frac{3}{4}$	223·40
4	8·81	8	70·49	12	237·94
$4\frac{1}{4}$	10·57	$8\frac{1}{4}$	77·32	$12\frac{1}{4}$	253·13
$4\frac{1}{2}$	12·55	$8\frac{1}{2}$	84·56	$12\frac{1}{2}$	268·97
$4\frac{3}{4}$	14·76	$8\frac{3}{4}$	92·24	$12\frac{3}{4}$	285·37
5	17·12	9	100·39	13	302·41
$5\frac{1}{4}$	19·93	$9\frac{1}{4}$	108·98	$13\frac{1}{4}$	320·80
$5\frac{1}{2}$	22·91	$9\frac{1}{2}$	118·06	$13\frac{1}{2}$	338·81
$5\frac{3}{4}$	26·18	$9\frac{3}{4}$	127·63	$13\frac{3}{4}$	357·93

1. What will be the weight of a hollow ball or shell of cast iron, the external diameter being $9\frac{1}{2}$, and internal diameter $8\frac{3}{4}$ inches?

Opposite $9\frac{1}{2}$ are 118·06, and
Opposite $8\frac{3}{4}$ are 92·24, subtract

— 25·82 lbs., weight required.

2. Requiring to remove a cast iron ball 37·8 lbs. in weight, and in diameter $6\frac{1}{2}$ inches, and replace it by one of lead of an equal weight, what must be the diameter of the leaden ball?

Weight of lead to that of cast iron $=1{\cdot}56$ (see Table, page 132.)

Then $\dfrac{6{\cdot}5^3}{1{\cdot}56} = \sqrt[3]{176} = 5{\cdot}6$ inches, the diameter.

TABLES BY WHICH TO FACILITATE THE MENSURATION OF TIMBER.

1. *Flat or Board Measure.*

Breadth in inches.	Area of a lineal foot.	Breadth in inches.	Area of a lineal foot.	Breadth in inches.	Area of a lineal foot.
$\frac{1}{4}$	·0208	4	·3334	8	·6667
$\frac{1}{2}$	·0417	$4\frac{1}{4}$	·3542	$8\frac{1}{4}$	·6875
$\frac{3}{4}$	·0625	$4\frac{1}{2}$	·375	$8\frac{1}{2}$	·7084
1	·0834	$4\frac{3}{4}$	·3958	$8\frac{3}{4}$	·7292
$1\frac{1}{4}$	·1042	5	·4167	9	·75
$1\frac{1}{2}$	·125	$5\frac{1}{4}$	·4375	$9\frac{1}{4}$	·7708
$1\frac{3}{4}$	·1459	$5\frac{1}{2}$	·4583	$9\frac{1}{2}$	·7917
2	·1667	$5\frac{3}{4}$	·4792	$9\frac{3}{4}$	·8125
$2\frac{1}{4}$	·1875	6	·5	10	·8334
$2\frac{1}{2}$	·2084	$6\frac{1}{4}$	·5208	$10\frac{1}{4}$	·8542
$2\frac{3}{4}$	·2292	$6\frac{1}{2}$	·5416	$10\frac{1}{2}$	·875
3	·25	$6\frac{3}{4}$	·5625	$10\frac{3}{4}$	·8959
$3\frac{1}{4}$	·2708	7	·5833	11	·9167
$3\frac{1}{2}$	·2916	$7\frac{1}{4}$	·6042	$11\frac{1}{4}$	·9375
$3\frac{3}{4}$	·3125	$7\frac{1}{2}$	·625	$11\frac{1}{2}$	·9583
		$7\frac{3}{4}$	·6458	$11\frac{3}{4}$	·9792

Application and Use of the Table.

1. Required the number of square feet in a board or plank $16\frac{1}{2}$ feet in length, and $9\frac{3}{4}$ inches in breadth.

Opposite $9\frac{3}{4}$ is $·8125 \times 16·5 = 13·4$ square feet.

2. A board 1 foot $2\frac{3}{4}$ inches in breadth, and 21 feet in length; what is its superficial content in square feet?

Opposite $2\frac{3}{4}$ is ·2292, to which add the 1 foot.
Then $1·2292 \times 21 = 25·8$ square feet.

3. In a board $15\frac{1}{2}$ inches at one end, 9 inches at the other, and $14\frac{1}{2}$ feet in length, how many square feet?

$$\frac{15·5+9}{2} = 12\tfrac{1}{4}, \text{ or } 1·0208; \text{ and } 1·0208 \times 14·5 = 14·8 \text{ sq. ft.}$$

2. *Cubic or Solid Measure.*

Mean ¼ girth in inches.	Cubic ft. in each lineal ft.	Mean ¼ girth in inches.	Cubic ft. in each lineal ft.	Mean ¼ girth in inches.	Cubic ft. in each lineal ft.
6	·25	14	1·361	22	3·362
6¼	·272	14¼	1·41	22¼	3·438
6½	·294	14½	1·46	22½	3·516
6¾	·317	14¾	1·511	22¾	3·598
7	·340	15	1·562	23	3·673
7¼	·364	15¼	1·615	23¼	3·754
7½	·39	15½	1·668	23½	3·835
7¾	·417	15¾	1·722	23¾	3·917
8	·444	16	1·777	24	4·
8¼	·472	16¼	1·833	24¼	4·084
8½	·501	16½	1·89	24½	4·168
8¾	·531	16¾	1·948	24¾	4·254
9	·562	17	2·006	25	4·34
9¼	·594	17¼	2·066	25¼	4·428
9½	·626	17½	2·126	25½	4·516
9¾	·659	17¾	2·187	25¾	4·605
10	·694	18	2·25	26	4·694
10¼	·73	18¼	2·313	26¼	4·785
10½	·766	18½	2·376	26½	4·876
10¾	·803	18¾	2·442	26¾	4·969
11	·84	19	2·506	27	5·062
11¼	·878	19¼	2·574	27¼	5·158
11½	·918	19½	2·64	27½	5·252
11¾	·959	19¾	2·709	27¾	5·348
12	1·	20	2·777	28	5·444
12¼	1·042	20¼	2·898	28¼	5·542
12½	1·085	20½	2·917	28½	5·64
12¾	1·129	20¾	2·99	28¾	5·74
13	1·174	21	3·062	29	5·84
13¼	1·219	21¼	3·136	29¼	5·941
13½	1·265	21½	3·209	29½	6·044
13¾	1·313	21¾	3·285	29¾	6·146

In the cubic estimation of timber, custom has established the rule of $\frac{1}{4}$ the mean girth being the side of the square considered as the cross sectional dimensions; hence, multiply the number of cubic feet per lineal foot, as in the Table of Cubic Measure, opposite the $\frac{1}{4}$ girth, and the product is the solidity of the given dimensions in cubic feet.

Suppose the mean $\frac{1}{4}$ girth of a tree $21\frac{1}{4}$ inches, and its length 16 feet, what are its contents in cubic feet?

$$3{\cdot}136 \times 16 = 50{\cdot}176 \text{ cubic feet.}$$

CAST METAL CYLINDERS.

The cylinders are solid, each 1 foot in length.

Diam.	Iron.	Copper.	Brass.	Lead.
inches.	lbs.	lbs.	lbs.	lbs.
1	2·5	3·0	2·9	3·9
2	9·8	12·0	11·4	15·5
3	22·1	27·0	25·8	34·8
4	39·3	47·9	45·8	61·9
5	61·4	74·9	71·6	96·7
6	88·4	107·8	103·0	139·3
7	120·3	146·8	140·2	189·6
8	157·1	191·7	183·2	347·7
9	198·8	242·7	231·8	313·4
10	245·4	299·5	286·2	387·0

CAST IRON PIPES.

This table shows the weight of pipes 1 foot long, of bores from 1 inch to 12 inches in diameter, advancing by $\frac{1}{4}$ of an inch; and of thicknesses from $\frac{1}{4}$ of an inch to $1\frac{1}{4}$ inches, advancing by $\frac{1}{8}$ of an inch.

bore.	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$
in.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3·1	5·1	7·4	10·0	12·9	16·1	19·6	23·5	27·6
$1\frac{1}{4}$	3·7	6·0	8·6	11·5	14·7	18·3	22·1	26·2	30·7
$1\frac{1}{2}$	4·3	6·9	9·8	13·0	16·6	20·4	24·5	29·0	33·7
$1\frac{3}{4}$	4·9	7·8	11·1	14·6	18·4	22·6	27·0	31·8	36·8
2	5·5	8·8	12·3	16·1	20·3	24·7	29·5	34·5	39·9
$2\frac{1}{4}$	6·1	9·7	13·5	17·6	22·1	26·8	31·9	37·3	43·0
$2\frac{1}{2}$	6·7	10·6	14·7	19·2	23·9	28·9	34·4	40·0	46·0
$2\frac{3}{4}$	7·4	11·5	16·0	20·7	25·7	31·1	36·8	42·8	49·1
3	8·0	12·4	17·2	22·2	27·6	33·3	39·3	45·6	52·2
$3\frac{1}{4}$	8·6	12·3	18·4	23·8	29·5	35·4	41·7	48·3	55·2
$3\frac{1}{2}$	9·2	14·2	19·6	25·3	31·3	37·6	44·2	51·1	58·3
$3\frac{3}{4}$	9·8	15·2	20·9	26·9	33·1	39·7	46·6	53·8	61·4
4	10·4	16·1	22·1	28·4	35·0	41·9	49·1	56·6	64·4
$4\frac{1}{4}$	11·1	17·1	23·4	30·0	36·9	44·1	51·6	59·4	67·6
$4\frac{1}{2}$	11·7	18·0	24·5	31·4	38·7	46·2	54·0	62·1	70·6
$4\frac{3}{4}$	12·3	18·9	25·8	33·0	40·5	48·3	56·5	64·9	73·6
5	12·9	19·8	27·0	34·5	42·3	50·5	58·9	67·6	76·7
$5\frac{1}{4}$	13·5	20·7	28·2	36·1	44·2	52·6	61·4	70·4	79·8
$5\frac{1}{2}$	14·1	21·6	29·5	37·6	46·0	54·8	63·8	73·2	82·8
$5\frac{3}{4}$	14·7	22·6	30·7	39·1	47·9	56·9	66·3	76·0	85·9
6	15·3	23·5	31·9	40·7	49·7	59·1	68·7	78·7	88·8
$6\frac{1}{4}$	16·0	24·4	33·1	42·2	51·5	61·2	71·2	81·2	92·0
$6\frac{1}{2}$	16·6	25·3	34·4	43·7	53·4	63·4	73·4	84·2	95·1
$6\frac{3}{4}$	17·2	26·2	35·6	45·3	55·2	65·3	76·1	87·0	98·2
7	17·8	27·2	36·8	46·8	56·8	67·7	78·5	89·7	101·2
$7\frac{1}{4}$	18·4	28·1	38·1	48·1	58·9	69·8	81·0	92·5	104·2
$7\frac{1}{2}$	19·0	29·0	39·1	49·9	60·7	72·0	83·5	95·3	107 4
$7\frac{3}{4}$	19·6	29·7	40·5	51·4	62·6	74·1	85·9	98·0	110·5
8	20·0	30·8	41·7	52·9	64·4	76·2	88·4	100·8	113·5
$8\frac{1}{4}$	20·9	31·7	43·0	54·5	66·3	78·4	90·8	103·5	116·6
$8\frac{1}{2}$	21·7	32·9	44·4	56·2	68·3	80·8	93·5	106·5	119·9
$8\frac{3}{4}$	22·1	33·6	45·4	57·5	70·0	82·7	95·7	109·1	122·7
9	22·7	34·5	46·6	59·1	71·8	84·8	98·2	111·8	125·8
$9\frac{1}{4}$	23·3	35·4	47·9	60·6	73·6	87·0	100·6	114·6	128·9
$9\frac{1}{2}$	23·9	36·4	49·1	62·1	75·5	89·1	103·1	117·4	131·9
$9\frac{3}{4}$	24·6	37·3	50·3	63·7	77·3	91·3	105·5	120·1	135·0
10	25·2	38·2	51·5	65·2	79·2	93·4	108·0	122·8	138·1
$10\frac{1}{4}$	25·8	39·1	52·8	66·7	81·0	95·6	110·4	125·6	141·1
$10\frac{1}{2}$	26·4	40·0	54·0	68·3	82·8	97·7	112·9	128·4	144·2
$10\frac{3}{4}$	27·0	41·0	55·2	69·8	84·7	99·9	115·4	131·2	147·3
11	27·6	41·9	56·5	71·3	86·5	102·0	117·8	133·9	150·3
$11\frac{1}{4}$	28·2	42·8	57·7	72·9	88·4	104·2	120·3	136·7	153·4
$11\frac{1}{2}$	28·8	43·7	58·9	74·4	90·2	106·3	122·7	139·4	156·4
$11\frac{3}{4}$	29·5	44·6	60·1	75·9	92·0	108·5	125·2	142·2	159·5
2	30·1	45·6	61·4	77·5	93·6	110·6	127·6	145·0	162·6

TABLE FOR COMPOSITIONS OF BRASS, &c.

3 parts	copper,	0	tin,	1	zinc,	for yellow brass.
2 "	"	0	"	1	"	for Spelter.
4 "	"	1	"	¼	"	for lathe bushes.
4 "	"	1	"	½	"	still harder.
6 "	"	1	"	0	"	for bearings of shafts.
5 "	"	1	"	½	"	for harder bearings.
7 "	"	1	"	0	"	fit for pulley blocks.
8 "	"	1	"	0	"	fit for wheels.
9 "	"	1	"	0	"	gun metal.

The effect of different degrees of heat on different bodies, according to Fahrenheit's scale, are shown below:—

	Degrees.
Cast iron thoroughly melted,	20577
Cast iron begins to melt,	17977
Greatest heat of a common smith's forge,	17327
Flint glass furnace, strongest heat,	15897
Welding heat of iron, greatest,	13427
Swedish copper melts,	4587
Brass melts,	3807
Iron red-hot in the twilight,	884
Heat of a common fire,	790
Iron bright red in the dark,	752
Zinc melts,	700
Mercury boils,	672
Lead melts,	594
The surface of polished steel becomes uniformly a deep blue,	580
The surface of polished steel becomes a pale straw color,	460
A mixture of 3 tin and 2 lead melts,	332

CENTRE,

In a general sense, denotes a point equally remote from the extremes of a line, surface, or solid.

CENTRE OF ATTRACTION

Of a body, is that point into which, if all its matter is collected, its action upon any remote particle would still be the same.

CENTRE OF EQUILIBRIUM

Is the same, in respect to bodies immersed in a fluid as the centre of gravity is to bodies in free space.

CENTRE OF FRICTION

Is that point in the base of a body on which it revolves, into which, if the whole surface of the base and the mass of the body were collected, and made to revolve about the centre of the base of the given body, the angular velocity destroyed by its friction would be equal to the angular velocity destroyed in the given body by its friction in the same time.

CENTRE OF GRAVITY

Of any body, or system of bodies, is that point upon which the body, or system of bodies, acted upon only by the force of gravity, will balance itself in all positions; hence it follows, that, if a line or plane, passing through the centre of gravity, be supported, the body or system will be also supported.

CENTRE OF GYRATION

Is that point into which, if the whole mass were collected, a given force, applied at a given distance, would produce the same angular velocity in the same time as if the bodies were disposed at their respective distances.

This point differs from the *Centre of Oscillation* only in this, that, in the latter case, the motion is produced

by the gravity of the body; but, in the former, the body is put in motion by some other force, acting at one place only.

COHESION

Is that species of attraction which, uniting particle to particle, retains together the component parts of the same mass; being thus distinguished from *adhesion*, or that species of attraction which takes place between the surfaces of similar or dissimilar bodies. The absolute cohesion of solids is measured by the force necessary to pull them asunder. Thus, if a rod of iron be suspended in a vertical position, having weight attached to its lower extremity till the rod breaks, the whole weight attached to the rod, at the time of fracture, will be the measure of its cohesive force, or absolute cohesion.

The particles of solid bodies, in their natural state, are arranged in such a manner, that they are in equilibrium in respect to the forces which operate on them; therefore, when any new force is applied, it is evident that the equilibrium will be destroyed, and that the particles will move among themselves till it be restored. When the new force is applied to pull the body asunder, the body becomes longer in the direction of the force, which is called the *extension;* and its area, at right angles to the direction of the force, contracts. When the force is applied to compress the body, it becomes shorter in the direction of the force, which is called the *compression;* and the area of its section, at right angles to the force, expands. In either case, a part of the heat, or any fluid that occupies the pores or interstices of the body, before the new force was made to act upon it, will be expelled.

CASE-HARDENING.

The hardness and polish of steel may be united, in a certain degree, with the firmness and cheapness of

malleable iron, by what is called *case-hardening;* an operation much practised, and of considerable use.

It is a superficial conversion of iron into steel, and only differs from *cementation* in being carried on for a shorter time. Some artists pretend to great secrets in the practice of this art, using saltpetre, sal-ammoniac, and other fanciful ingredients, to which they attribute their success. But it is now an established fact, that the greatest effect may be produced by a perfectly tight box, and animal carbon alone.

The goods intended to be case-hardened, being previously finished, with the exception of polishing, are stratified with animal carbon, and the box containing them luted with equal parts of sand and clay. They are then placed in the fire, and kept at a light red heat for half an hour, when the contents of the box are emptied into water. Delicate articles, like files, may be preserved by a saturated solution of common salt, with any vegetable mucilage, to give it a pulpy consistence. The carbon here spoken of is nothing more than any animal matter, such as horns, hoofs, skins, or leather, just sufficiently burned to admit of being reduced to powder. The box is commonly made of iron, but the use of it, for occasional case-hardening upon a small scale, may easily be dispensed with, as it will answer the same end to envelop the articles with the composition above directed to be used as a lute, drying it gradually before it is exposed to a red heat, otherwise it will probably crack. It is easy to infer, that the depth of the steel, induced by case-hardening, will vary with the time the operation is continued. It may be varied from one hour to four, according to the depth of steel required. In one hour, it will scarcely be the thickness of a fourpence, and therefore may be removed by violent abrasion, though sufficient to answer well for fire-irons, and a multitude of other utensils, in the common usage of which its hardness prevents its being easily scratched, and its polish preserved by friction with so soft a material as leather.

To estimate, by means of an indicator, the amount of effective power produced by a steam-engine.

Rule.—Multiply the area of the piston in square inches by the average force of the steam in lbs., and by the velocity of the piston in feet per minute; divide the product by 33,000, and $\frac{7}{10}$ths of the quotient equal the effective power.

Ex. Suppose an engine with a cylinder of 37½ inches diameter, a stroke of 7 feet, and making 17 revolutions per minute, or 238 feet velocity, and the average indicated pressure of the steam 16·73 lbs. per square inch, required the effective power.

$$\frac{\text{Area} = 1104{\cdot}4687 \text{ inches} \times 16{\cdot}73 \text{ lbs.}, \times 238 \text{ feet.}}{33000}$$

$$= \frac{133{\cdot}26 \times 7}{10} \; 93{\cdot}282 \text{ horses' power.}$$

To determine the proper velocity for the piston of a steam-engine.

Rule.—Multiply the logarithm of the *n*th part of the stroke at which the steam is cut off by 2·3, and to the product of which add ·7. Multiply the sum by the distance in feet the piston has travelled when the steam is cut off, and 120 times the square root of the product equal the proper velocity for the piston in feet per minute.

Ex. Let the steam be cut off in an 8-feet stroke when the piston has travelled ¼th of the length; required its proper velocity.

Logarithm of 4 =	0·60206
Multiplied by	2·3
	1·384738
To which add	·7
	2·084738
	2

$\sqrt{4{\cdot}169476} = 2{\cdot}04 \times 120 = 245$ feet, velocity per minute

Table of Approximate Velocities for the Pistons of Steam-Engines.

Condensing Engines.			Non-condensing Engines.		
Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per min.	Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per min.
2	160	40	1½	186	62
2½	177½	35½	2	200	50
3	192	32	2½	212½	42½
3½	203	29	2¾	217¼	39½
4	214	26¾	3	222	37
4½	220½	24½	3½	231	33
5	230	23	4	236	29½
5½	236½	21½	4½	243	27
6	240	20	5	247½	24¾
7	245	17½	5½	253	23
8	256	16	6	264	22

Of the Parallel Motion in a Steam-Engine.

When the power from the piston is communicated by means of a beam or lever moving upon an axis, the parallel motion becomes a very important portion of the machine; for then it forms the link of connection, and by its properties renders the action of alternate circular motion, and reciprocating vertical motion, mutually agreeable, thereby properly insuring to the piston rod a truly direct line to that of the cylinder; but to effect this, the greatest degree of exactitude of the various parts is required, otherwise extra friction is created, and the effective power of the engine proportionately diminished.

Table by which to determine the various Distances of the Movable Points in a Parallel Motion.

Radius of beams in feet.	Parallel bars in feet.	Length of radius rods in feet and inches.
4 feet.	2	2 0
	2¼	1 4⅜
	2½	0 10⅞
	2¾	0 6⅞
	3	0 4
4½ feet.	2	3 1½
	2¼	2 3
	2½	1 7¼
	2¾	1 1⅝
	3	0 9
	3¼	0 5¾
5 feet.	2	4 6
	2¼	3 4¾
	2½	2 6
	2¾	1 10⅛
	3	1 4
	3¼	0 11¼
	3½	0 7¾
5½ feet.	2¼	4 8⅜
	2½	3 7¼
	2¾	2 9
	3	2 1
	3¼	1 6⅜
	3½	1 1¾
	3¾	0 9⅞
6 feet.	2¾	3 10
	3	3 0
	3¼	2 3⅞
	3½	1 9½
	3¾	1 4¼
	4	1 0
	4¼	0 8½

Radius of beams in feet.	Parallel bars in feet.	Length of radius rods in feet and inches.
6½ feet.	3	4 1⅛
	3¼	3 3
	3½	2 6⅞
	3¾	2 0¼
	4	1 6¾
	4¼	1 2⅛
	4½	0 10⅞
7 feet.	3	5 4
	3¼	4 4
	3½	3 6
	3¾	3 2⅞
	4	2 3
	4¼	1 9
	4½	1 4⅝
	4¾	1 0⅞
	5	0 9⅝
7½ feet.	3½	4 6⅞
	3¾	3 9
	4	3 0¾
	4¼	2 6
	4½	2 0
	4¾	1 7
	5	1 3
	5¼	0 11½
8 feet.	3½	5 9½
	3¾	4 9¾
	4	4 0
	4¼	3 3¾
	4½	2 8⅜
	4¾	2 2¾
	5	1 9⅝
	5¼	1 5¼

Radius of beams in feet.	Parallel bars in feet.	Length of radius rods in feet and inches.
8½ feet.	3¾	6 0¼
	4	5 6¾
	4¼	4 3
	4½	3 6⅝
	4¾	2 11⅛
	5	2 5⅜
	5¼	2 0⅛
	5½	1 7⅝
9 feet.	4	6 3
	4¼	5 3¾
	4½	4 6
	4¾	3 9⅝
	5	3 2⅛
	5¼	2 8⅛
	5½	2 2¾
	5¾	1 10
	6	1 6
9½ feet.	4½	5 6⅝
	4¾	4 9
	5	4 0⅝
	5¼	3 5⅜
	5½	2 10⅞
	5¾	2 5¼
	6	2 0½
10 feet.	4¾	5 9½
	5	5 0
	5¼	4 3½
	5½	3 8⅛
	5¾	3 1¾
	6	2 8
	6¼	2 3
	6½	1 10½

Radius of beams in feet.	Parallel bars in feet.	Length of radius rods in feet and inches.
10½ feet.	5	6 0½
	5¼	5 3
	5½	4 6½
	5¾	3 11
	6	3 3¼
	6¼	2 10¾
	6½	2 5⅜
	6¾	2 1
11 feet.	5¼	6 3½
	5½	5 6
	5¾	4 9½
	6	4 2
	6¼	3 7⅜
	6½	3 1⅜
	6¾	2 8⅛
11½ feet.	5½	6 6½
	5¾	5 9
	6	5 0½
	6¼	4 5
	6½	3 10⅛
	6¾	3 4
	7	2 10⅝
	7¼	2 6
12 feet.	5¾	6 8¼
	6	6 0
	6¼	5 3½
	6½	4 7⅞
	6¾	4 1
	7	3 6⅞
	7¼	3 1⅜
	7½	2 8½
	7¾	[illegible] 4

LOGARITHMS.

LOGARITHMS literally signify *ratios of numbers;* hence Logarithmic Tables may be various, but those in common use for the facilitating of arithmetical operations generally are of the following corresponding progressions, viz.: —

Arithmetical, 0, 1, 2, 3, &c., or series of logarithms.
Geometrical, 1, 10, 100, 1000, &c., or ratio of numbers.

And thus it may be perceived, that if the log. of 10 be 1, the log. of any number less than 10 must consist wholly of decimals, because increasing by a decimal ratio. Again; if the log. of 100 be 2, the log. of any intermediate number between 10 and 100 must be 1, with so many decimals annexed; and in like manner, the log. of any intermediate number between 100 and 1000, must be 2, with decimals annexed proportionally, as before.

APPLICATION AND UTILITY OF COMMON LOGARITHMIC TABLES.

The whole numbers of the series of logarithms, as 1, 2, 3, &c., are called the indices, or characteristics of the logarithm, and which must be added to the logarithm obtained by the Table, in proportion to the number of figures contained in the given sum. Thus, suppose the logarithm be required for a sum of only two figures, the index is 1; if of three figures, the index is 2; and if of four figures, the index is 3, &c.; being always a number less by unity than the number of figures the given sum contains.

Ex. The index of 8 is 0, because it is less than 10
The index of 80 is 1, because it is less than 100.
The index of 800 is 2, because it is less than 1000.
The index of 8000 is 3, because it is less than 10,000, &c.

The index of a decimal is always the number which denotes the significant figure from the decimal point, and is marked with the sign, thus, —, to distinguish it from a whole number.

Ex. The index of ·32549 is — 1, because the first significant figure is the first decimal.

The index of ·032549 is — 2, because the first significant figure is the second decimal.

The index of ·0032549 is — 3, because the first significant figure is the third decimal, &c., of any other sum.

If the given sum for which the logarithm is required contains or consists of both integers and decimals, the index is determined by the integer part, without having any regard to the other.

1. *To find the logarithm of any whole number under* 100.

Look for the number under N in the first page of any Logarithmic Table; then immediately on the right of it is the logarithm required, with its proper index. Thus the log. of 64 is 1·806180, and the log. of 72 is 1·857332.

2. *To find the logarithm of any number between* 100 *and* 1000, *or any sum not exceeding* 4 *figures.*

Find the first three figures in the left-hand column of the page under N, in which the number is situated, and the fourth figure, at the top or bottom of the page; then the logarithm directly under the fourth figure, and in a line with the three figures in the column on the left, with its proper index, is the logarithm re-

quired. Thus, the log. of 450 is 2·653213, and the log of 7464 is 3·872972. Or, the log. of 378·5 is 2·578066, and that of ·7854 is — 1·895091.

3. *To find the number indicated by a given logarithm*

Look for the decimal part of the given logarithm in the different columns, and if it cannot be found exactly, take the next less. Then under N in the left-hand column, and in a line with the logarithm found, are three figures of the number required, and on the top of the column in which the found logarithm stands is one figure more; place the decimal point as indicated by the logarithmic index, which determines the sum, properly valued, as required.

If the logarithm cannot be found exactly in the Tables, subtract from it the next less that can be found, and divide the remainder by the tabular difference; the quotient will be the rest of the figures of the given number, which, being annexed to the tabular number already found, is the proper number required.

Ex. Required the number answering to the logarithm 3·233568.

Given logarithm . . . . = 3·233568
Next less is the log. of 1712 = 3·233504

Remainder 64

Tab. Diff. = 253, and $\frac{64}{253} = {\cdot}25$

Hence the number required = 1712·25.

For practical purposes in mechanics, logarithms are seldom resorted to, unless for the raising of the powers of numbers or extraction of their roots. These operations, when tables are at hand, they very much facilitate; involution, or the raising of powers, being performed simply by multiplication, and evolution, or the extraction of roots, by division, as in simple arithmetic.

Ex. 1. Required the square or second power of 25·791.

Log. of 25·791 = 1·411468
Multiplied by 2 the power required.

Logarithm 2·822936 indicated number or square required = 665·175.

Ex. 2. What is the cube of 30·7146?

Logarithm = 1·487345
Multiplied by 3 the power required.

Logarithm 4·462035 indicated number or cube required = 28975·7.

Ex. 3. Required the square root of 365.

Log. $= \frac{2\cdot562293}{2} = 1\cdot281146$ indicated number or root = 19·105.

Ex. 4. Find the cube root of 12345.

Log. $= \frac{4\cdot091491}{3} = 1\cdot363830$ indicated number or root = 23·1116.

Table of Logarithms from 1 to 100.

N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0·000000	26	1·414973	51	1·707570	76	1·880814
2	0·301030	27	1·431364	52	1·716003	77	1·886491
3	0·477121	28	1·447158	53	1·724276	78	1·892095
4	0·602060	29	1·462398	54	1·732394	79	1·897627
5	0·698970	30	1·477121	55	1·740363	80	1·903090
6	0·778151	31	1 491362	56	1·748188	81	1·908485
7	0·845098	32	1·505150	57	1·755875	82	1·913814
8	0·903090	33	1·518514	58	1 763428	83	1·919078
9	0·954243	34	1·531479	59	1·770852	84	1·924279
10	1·000000	35	1·544068	60	1·778151	85	1·929419
11	1·041393	36	1·556303	61	1·785330	86	1·934498
12	1·079181	37	1·568202	62	1·792392	87	1·939519
13	1·113943	38	1·579784	63	1·799341	88	1·944483
14	1·146128	39	1·591065	64	1·806180	89	1·949390
15	1·176091	40	1·602060	65	1·812913	90	1·954243
16	1·204120	41	1·612784	66	1·819544	91	1·959041
17	1·230449	42	1·623249	67	1·826075	92	1·963788
18	1 255273	43	1·633468	68	1·832509	93	1·968483
19	1·278754	44	1·643453	69	1·838849	94	1·973128
20	1·301030	45	1·653213	70	1·845098	95	1·977724
21	1·322219	46	1·662758	71	1·851258	96	1·982271
22	1·342423	47	1·672098	72	1·857332	97	1·986772
23	1·361728	48	1·681241	73	1·863323	98	1·991226
24	1·380211	49	1·690196	74	1·869232	99	1·995635
25	1·397940	50	1·698970	75	1·875061	100	2·000000

Note. — The best Tables of Logarithms are those by Taylor, Gardiner, Hutton, Babbage, and Caillet. The smaller works are those by Lalande, Hassler, Renaud, Christison, and Wallace, and those published in the "Library of Useful Knowledge.

TABLE — WATER IN PIPES.

This table shows the quantity and weight of water contained in one fathom of length of pipes of different bores from 1 inch to 12 inches in diameter, advancing by half inch. The weight of a cubic foot of water is taken at 1000 ounces avoirdupois, and the imperial gallon at 10 lbs.

Diameter in inches.	Quantity in cubic inches.	Quantity in imperial gallons.	Weight in lbs. avoirdupois.
½	14·14	0·051	0·51
1	56·55	0·205	2·05
1½	127·23	0·460	4·60
2	226·19	0·818	8·18
2½	353·43	1·278	12·78
3	508·94	1·841	18·41
3½	692·72	2·506	25·06
4	904·78	3·272	32·72
4½	1145·11	4·142	41·42
5	1413·72	5·113	51·13
5½	1710·60	6·187	61·87
6	2035·75	7·363	73·63
6½	2389·18	8·641	86·41
7	2770·88	10·022	100·22
7½	3180·86	11·505	115·05
8	3619·11	13·090	130·90
8½	4085·64	14·777	147·77
9	4580·44	16·567	165·67
9½	5103·52	18·459	184·59
10	5654·87	20·453	204·53
10½	6234·49	22·550	225·50
11	6842·39	24·748	247·48
11½	7478·56	27·049	270·49
12	8143·01	29·452	294·52

CHANGES INDUCED IN THE STRUCTURE OF IRON SUBSEQUENT TO MANUFACTURE.

The important purposes to which iron is applied have always rendered it a subject of peculiar interest; and at no period has its importance been so general and extensive as at the present time, when its application is almost daily extending, and there is scarcely any thing connected with the arts to which, either directly or indirectly, it does not in some degree contribute. My object is to point out some peculiarities in the habitudes of iron, which appear to have almost wholly escaped the attention of scientific men, and which, although in some degree known to practical mechanics, have been generally considered by them as isolated facts, and not regarded as the results of a general law. The circumstances, however, well deserve the attention of scientific men, on account of the very important consequences to which they lead.

The two great distinctions, which exist in malleable wrought iron, are known by the names of *red-short* and *cold-short* qualities. The former of these comprises the tough, fibrous iron, which generally possesses considerable strength when cold; the latter shows a bright, crystallized fracture, and is very brittle when cold, but works ductile while hot. These distinctions are perfectly well known to all those who are conversant with the qualities of iron; but it is not generally known that there are several ways by which the tough, red-short iron becomes rapidly converted into the crystallized; and that, by this change, its strength is diminished to a very great extent. The importance which attaches to this subject will not be denied. The principal causes which produce this change are percussion, heat, and magnetism; and it is doubtful whether either of these means will produce this effect; and there appear strong reasons for supposing that, generally, they are all in

some degree concerned in the production of the observed results. The most common exemplification of the effect of heat, in crystallizing fibrous iron, is by breaking a wrought-iron furnace-bar; which, whatever quality it was of in the first instance, will, in a short time, invariably be converted into crystallized iron; and, by heating, and rapidly cooling by quenching with water a few times, any piece of wrought iron, the same effect may be far more speedily produced. In these cases, we have at least two of the above causes in operation — heat and magnetism. In every instance of heating iron to a very high temperature, it undergoes a change in its electric or magnetic condition; for, at very high temperatures, iron entirely loses its magnetic powers, which return, as it gradually cools to a lower temperature. In the case of quenching the heated iron with water, we have a still more decisive assistance from the electric and magnetic forces; for Sir Humphrey Davy long since pointed out, that all cases of vaporization produced negative electricity in the bodies in contact with the vapor; — a fact which has lately excited a good deal of attention, in consequence of the discovery of large quantities of negative electricity in effluent steam. These results, however, are practically of but little consequence; but the effects of percussion are at once various, extensive, and of high importance. We shall trace these effects under several different circumstances.

In the manufacture of some descriptions of hammered iron, the bar is first rolled into shape, and then one-half the length of the bar is heated in a furnace, and immediately taken to the tilt-hammer and hammered; and the other end of the bar is then heated and hammered in the same manner. In order to avoid any unevenness in the bar, or any difference in its color where the two distinct operations have terminated, the workman frequently gives the bar a few blows with the hammer on that part which he first operated upon. That part of the bar has, however, by this time,

become comparatively cold; and, if this cooling process has proceeded too far when it receives this additional hammering, that part of the bar immediately becomes crystallized, and so extremely brittle that it will break to pieces by merely throwing it on the ground, though all the rest of the bar will exhibit the best and toughest quality imaginable. This change, therefore, has been produced by percussion as the primary agent. We here see the effects of percussion in a very instructive form. And it must be observed, that it is not the excess of hammering which produces the effect, but the absence of a sufficient degree of heat at the time the hammering takes place; and the evil may probably be all produced by five or six blows of the hammer, if the bar happens to be of a small size. In this case, we witness the combined effects of percussion, heat, and magnetism. When the bar is hammered at the proper temperature, no such crystallization takes place, because the bar is insensible to magnetism; but, as soon as the bar becomes of that lower degree of temperature at which it can be affected by magnetism, the effect of the blows it receives is to produce magnetic induction; and that magnetic induction, and consequent polarity of its particles, when assisted by further vibrations from additional percussion, produces a crystallized texture. For it is perfectly well known that, in soft iron, magnetism can be almost instantaneously produced by percussion; and it is probable that, the higher the temperature of the bar at the time it receives the magnetism, the more likely will it be to allow of that rearrangement of its molecules which would constitute the crystallization of the iron. It is not difficult to produce the same effects by repeated blows from a hand-hammer on small bars of iron; but it appears to depend upon something peculiar in the blow, which, to produce the effect, must occasion a complete vibration among the particles in the neighborhood of the part which is struck. And it is remarkable that the effects of the blows, in all cases.

seem to be confined within certain limited distances of the spot which receives the strokes.

Dr. Wollaston first pointed out that the forms in which native iron is disposed to break, are those of the regular octahedron and tetrahedron, or rhomboid, consisting of these forms combined. The tough and fibrous character of wrought iron is entirely produced by art; and we see, in these changes that have been described, an effort at returning to the natural and primal form; — the crystalline structure, in fact, being the natural state of a large number of metals; — and Sir Humphrey Davy has shown, that all those which are fusible by ordinary means assume the form of regular crystals by slow cooling. The general conclusion, to which these remarks lead us, appears to leave no doubt that there is a constant tendency in wrought iron, under certain circumstances, to return to the crystallized state; but that this crystallization is not necessarily dependent upon time for its development, but is determined solely by other circumstances, of which the principal is, undoubtedly, vibration. Heat, within certain limits, though greatly assisting the rapidity of the change, is certainly not essential to it; but magnetism, induced either by percussion or otherwise, is an essential accompaniment of the phenomena attending the change.

STRENGTH OF JOURNALS OF SHAFTS.

Mr. Buchanan's rule is — The cube root of the weight in cwts. is nearly equal to the diameter of the journal; — it being prudent to make the journal a little more than less, and to make a due allowance for wearing.

Ex. What is the diameter of a journal of a water-wheel shaft, 13 feet long, the weight of the wheel being 15 tons?

By Mr. B.'s rule,

$$\sqrt[3]{15 \times 20} = 6{\cdot}7, \text{ or 7 inches diameter.}$$

By Mr. Tredgold's rule,

$$\text{Weight in the middle, } \frac{3360}{500} \times 13 = 873 \quad \sqrt[3]{873} = 9\tfrac{1}{2} \text{ inches diameter.}$$

$$\text{Weight equally distributed, } 33600 \times 13 = 436800 \quad \sqrt[3]{\frac{436800}{10}} = 7{\cdot}65 \text{ inches.}$$

To resist Torsion or Twisting.

It is obvious that the strength of revolving shafts* are directly as the cubes of their diameters and revolutions; and inversely, as the resistance they have to overcome.

Mr. Robertson Buchanan, in his essay on the Strength of Shafts, gives the following data, deduced from several experiments, viz.: That the fly-wheel shaft of a 50-horse-power engine, at 50 revolutions per minute, requires to be 7½ inches diameter; and therefore, the cube of this diameter, which is $= 421{\cdot}875$, serves as a multi-

* Shafts, here, are understood as the journals of shafts, the bodies of shafts being generally made square.

plier to all other shafts in the same proportion; and, taking this as a standard, he gives the following multipliers, viz.: —

For the shaft of a steam-engine, water-wheel, or any shaft connected with a first power, ... 400
For shafts in inside of mills, to drive smaller machinery, or connected with the shafts above, ... 200
For the small shafts of a mill or machinery, ... 100

From the foregoing, the following rule is derived, viz.: The number of horses' power a shaft is equal to, is directly as the cube of the diameter and number of revolutions; and inversely, as the above multipliers.

Ex. 1. When the fly-wheel shaft of a 45-horse-power steam-engine makes 90 revolutions per minute, what is the diameter of the journal?

$$\frac{45 \times 400}{90} = 200 \quad \sqrt[3]{200} = 5\tfrac{8}{10} \text{ inches diameter.}$$

Ex. 2. The velocity of a shaft is 80 revolutions per minute, and its diameter is 3 inches; what is its power?

$$\frac{3^3 \times 80}{400} = 5{\cdot}4 \text{ horses' power.}$$

Ex. 3. What will be the diameter of the shaft in the first example, when used as a shaft of the second multiplier?*

$$\frac{5{\cdot}8}{1{\cdot}25} = 4{\cdot}64, \text{ or } \sqrt[3]{\frac{45 \times 200}{90}} = 4\tfrac{6}{10} \text{ inches diameter}$$

The following is a table of the diameters of shafts, being the first movers, or having 400 for their multipliers.

* The diameters of the second movers will be found by dividing the numbers in the Table by 1·25, and the diameters of the third movers, by dividing the numbers by 1·56.

Horses' power.	Revolutions. 10	15	20	25	30	35	40	45	50	55
	Inches Diameter.									
4	5.5	4·8	4·5	4·	3·7	3·8	3·5	3·3	3·2	3·1
5	5·9	5·1	4·7	4·4	4·1	3·9	3·7	3·6	3·5	3·3
6	6·3	5·5	5·	4·6	4·4	4·1	4·	3·8	3·7	3·6
7	6·6	5·8	5·2	4·9	4·6	4·4	4·2	4·	3·9	3·7
8	6·9	6·	5·5	5·1	4·8	4·6	4·4	4·2	4·1	4·
9	7·2	6·3	5·7	5·5	5·	4·8	4·5	4·4	4·2	4·1
10	7·4	6·6	5·9	5·6	5·2	4·9	4·7	4·6	4·4	4·2
12	7·9	6·9	6·3	5·8	5·6	5·4	5·2	5·	4·8	4·6
14	8·3	7·2	6·7	6·2	5·9	5·6	5·4	5·2	5·	4·7
16	8·7	7·6	7·1	6·6	6·1	5·8	5·6	5·4	5·2	5·
18	9·	7·9	7·5	7·	6·6	6·2	5·8	5·6	5·4	5·2
20	9·3	8·1	7·7	7·2	6·8	6·4	5·9	5·7	5·6	5·4
25	10·	8·5	8·	7·4	7·1	6·8	6·3	6·	5·9	5·6
30	10·7	9·3	8·4	7·9	7·4	7·1	6·9	6·7	6·5	6·3
35	11·4	9·8	8·9	8·4	7·9	7·4	7·1	6·9	6·6	6·5
40	11·7	10·5	9·3	8·8	8·3	7·8	7·4	7·2	6·9	6·7
45	12·	10·6	9·7	9·2	8·7	8·1	7·6	7·4	7·	6·8
50	12·6	11·	10·	9·3	9·	8·5	8·	7·8	7·4	7·3
55	13·4	11·4	10·4	9·8	9·1	8·8	8·4	8·	7·5	7·4
60	13·6	12·	10·8	10·	9·3	9·	8·6	8·2	7·7	7·6

Horses' power.	Revolutions.									
	60	65	70	75	80	85	90	95	100	105
	Inches Diameter.									
4	3·	2·9	2·9	2·8	2·7	2·7	2·6	2·6	2·6	2·5
5	3·3	3·2	3·1	3·	3·	2·9	2·9	2·8	2·8	2·7
6	3·5	3·5	3·4	3·3	3·2	3·2	3·	3·	2·9	2·9
7	3·6	3·6	3·5	3·4	3·4	3·3	3·3	3·2	3·1	3·1
8	3·9	3·8	3·7	3·6	3·5	3·5	3·4	3·4	3·3	3·2
9	4·	3·8	3·7	3·7	3·6	3·6	3·5	3·5	3·4	3·3
10	4·1	4·	3·9	3·8	3·7	3·7	3·6	3·6	3·5	3·4
12	4·4	4·3	4·2	4·1	4·	3·9	3·8	3·8	3·7	3·6
14	4·5	4·4	4·4	4·3	4·2	4·1	4·	4·	3·9	3·8
16	4·8	4·7	4·6	4·5	4·4	4·4	4·3	4·2	4·1	4·
18	5·	4·9	4·8	4·7	4·6	4·5	4·4	4·3	4·2	4·2
20	5·2	5·1	5·	4·8	4·6	4·6	4·5	4·5	4·4	4·4
25	5·5	5·4	5·3	5·2	5·1	4·9	4·8	4·7	4·6	4·6
30	5·9	5·8	5·7	5·6	5·5	5·3	5·2	5·1	5·	4·9
35	6·3	6·1	5·9	5·7	5·6	5·5	5·4	5·3	5·2	5·2
40	6·6	6·4	6·2	6·	5·9	5·8	5·7	5·6	5·6	5·5
45	6·7	6·5	6·4	6·2	6·1	6·	5·9	5·8	5·7	5·6
50	7·2	6·9	6·8	6·6	6·5	6·4	6·2	6·	5·9	5·8
55	7·3	7·2	7·	6·7	6·6	6·5	6·3	6·2	6·1	6·
60	7·4	7·3	7·2	6·9	6·8	6·8	6·7	6·6	6·4	6·2

It is a well known fact, that a cast iron rod will sustain more torsional pressure than a malleable iron rod of the same dimensions; that is, a malleable iron rod will be twisted by a less weight than what is required to wrench a cast iron rod of the same dimensions.

When the strength of malleable is less than that of cast iron to resist torsion, it is stronger than cast iron to resist lateral pressure, and that is in proportion as 9 is to 14.

From the foregoing, it is easy for the millwright to make his shafts of the iron best suited to overcome the resistance to which they will be subject, and the proportion of the diameters of their journals, according to the iron of which they are made.

Ex. What will be the diameter of a malleable iron journal to sustain an equal weight with a cast iron journal of 7 inches diameter.

$7^3 = 343$.
As $14 : 343 :: 9 : 220\frac{1}{2}$; now $\sqrt[3]{220{\cdot}5} = 6{\cdot}04$ inches diameter.

STRENGTH OF WHEELS.

The arms of wheels are as levers fixed at one end, and loaded at the other; and, consequently, the greatest strain is upon the end of the arm next the axle. For that reason, all arms of wheels should be strongest at that part, and tapering toward the rim.

The rule for the breadth and thickness of arms, according to their length and number in the wheel, is as follows: Multiply the power or weight acting at the end of the arm by the cube of its length; the product of which, divided by 2656 times the number of arms multiplied by the deflection, will give the breadth, and cube of the depth.

Ex. Suppose the force acting at the circumference of a spur-wheel to be 1600 lbs., the radius of wheel 6

feet, and number of arms 8, and let the deflection not exceed $\frac{1}{10}$th of an inch.

$$\frac{1600 \times 6^3}{2656 \times 8 \times 1} = 163 = \text{breadth and cube of the depth}$$

Let the breadth be 2·5 inches; therefore, $\frac{163}{2 \cdot 5} = 65 \cdot 2$;

which is equal to the cube of the depth. Now the cube root of 65·2 is nearly 4·03 inches: this, consequently, is the depth or dimension of each arm in the direction of the force.

Note.—When the depth at the rim is intended to be half that of the axes, use 1640 as a divisor instead of 2656.

The teeth are as beams, or cantilevers, fixed at one end and loaded at the other. The rule applying directly to them where the length of the beam is the length of the teeth, and the depth the thickness of the teeth. For the better explanation of the rule, the following example is given.

Ex. The greatest power acting at the pitch line of the wheel is 6000 lbs., and the thickness of the teeth $1\frac{1}{2}$ inch, the length of the teeth being 0·25 feet; it is required to determine the breadth of the teeth.

$$\frac{6000 \times 0 \cdot 25}{212 \times 1 \cdot 5^2} = \frac{1500}{477} = 3 \cdot 2 \text{ inches, the breadth required.}$$

In order that the teeth may be capable of offering a sufficient resistance after being worn by friction, the breadth thus found should be doubled; therefore, in the above example, the breadth should be 6·4, or say $6\frac{1}{2}$ inches.

The following data are gleaned from experiments, which are, therefore, valuable, and of much use to the practical mechanic.

Rule.—Multiply the breadth of the teeth by the square of the thickness, and divide the product by the length; the quotient will be the proportional strength in horses' power, with a velocity of 2·27 feet per second.

Ex. What is the power of a wheel, the teeth of which are 6 inches broad, 1·5 inch thick, and 1·8 inch long, and revolving at the velocity of 3 feet per second?

$\frac{\cdot 5^2 \times 6}{1\cdot 8} = \frac{13\cdot 5}{1\cdot 8} = 7\cdot 5$, strength at 2·27 feet per second; then

$$2\cdot 27 : 7\cdot 5 :: 3 = \frac{7\cdot 5 \times 3}{2\cdot 27} = 9\cdot 91 \text{ horses' power.}$$

Rule. — The pitch is found by multiplying the thickness by 2·1, and the length is found by multiplying the thickness by 1·2.

Ex. The thickness being 2 inches, what is the pitch and length?

$$2 \times 2\cdot 1 = 4\cdot 2, \text{ pitch.}$$
$$2 \times 1\cdot 2 = 2\cdot 4, \text{ length}$$

Note. — The breadth of the teeth, as commonly executed by the best mechanics, seems to be from about twice to thrice the pitch.

Pitch in in.	Thickness in inches.	Breadth in inches.	Length in inches.	Horses' power, at 2·27 feet per second.	Horses' power, at 3 feet per second.	Horses' power, at 6 feet per second.
4·2	2·	8·	2·40	13·33	17·61	35·23
3·99	1·9	7·6	2·28	13·03	15·90	31·80
3·78	1·8	7·2	2·16	10·80	14·27	28·54
3·57	1·7	6·8	2·04	9·63	12·72	25·54
3·36	1·6	6·4	1·92	8·53	11·27	22·54
3·15	1·5	6·	1·80	7·50	9·91	19·82
2·94	1·4	5·6	1·68	6·53	8·63	17·26
2·73	1·3	5·2	1·56	5·63	7·44	14·88
2·52	1·2	4·8	1·44	4·80	6·34	12·68
2·31	1·1	4·4	1·32	4·03	5·32	10·64
2·10	1·	4·	1·20	3·33	4·40	8·81
1·89	·9	3·6	1·08	2·70	3·57	7·14
1·68	·8	3·2	·96	2·13	2·81	5·62
1·47	·7	2·8	·84	1·63	2·15	4·30
1·26	·6	2·4	·72	1·20	1·59	3·18
1·05	·5	2·	·60	·83	1·10	2·20

TABLES

OF THE

CIRCUMFERENCES OF CIRCLES,

TO THE

NEAREST FRACTION OF PRACTICAL MEASUREMENT,

ALSO THE

AREAS OF CIRCLES

IN INCHES AND DECIMAL PARTS, LIKEWISE IN FEET AND DECIMAL PARTS, AS MAY BE REQUIRED.

Rules that may render the following Tables more generally useful.

1. Any of the areas in inches multiplied by ·04328, or the areas in feet multiplied by 6·232, the product is the number of imperial gallons at 1 foot in depth.

2. Any of the areas in feet multiplied by ·03704, the product equal the number of cubic yards at 1 foot in depth.

3. The area of a circle in inches multiplied by the length or thickness in inches, and by ·263, the product equal the weight in lbs. of cast iron.

Note.—The French cubic metre, or unit of solid measure, equal 35·31716 English cubic feet. Also the litre, or unit for measures of capacity, equal 61·028 English cubic inches, or about ·453 of an imperial gallon.

Dia. in inch.	Circum. in inch.	Area in sq. inch.	Side of = squ.
1/16	·196	·0030	·0554
1/8	·392	·0122	·1107
3/16	·589	·0276	·1661
1/4	·785	·0490	·2115
5/16	·981	·0767	·2669
3/8	1·178	·1104	·3223
7/16	1·374	·1503	·3771
1/2	1·570	·1963	·4331
9/16	1·767	·2485	·4995
5/8	1·963	·3068	·5438
11/16	2·159	·3712	·6093
3/4	2·356	·4417	·6646
13/16	2·552	·5185	·7200
7/8	2·748	·6013	·7754
15/16	2·945	·6903	·8308
1 in.	3 1/8	·7854	7/8
1 1/8	3 1/2	·9940	7/8 & 3/32
1 1/4	3 7/8	1·227	1 in.
1 3/8	4 1/4	1·484	1 3/16
1 1/2	4 5/8	1·767	1 5/16
1 5/8	5 1/8	2·074	1 7/16
1 3/4	5 1/2	2·405	1 9/16
1 7/8	5 7/8	2·761	1 11/16
2 in.	6 1/4	3·141	1 3/4
2 1/8	6 5/8	3·546	1 7/8
2 1/4	7	3·976	2 in.
2 3/8	7 3/8	4·430	2 1/8
2 1/2	7 3/4	4·908	2 3/16
2 5/8	8 1/4	5·412	2 5/16
2 3/4	8 5/8	5·939	2 7/16
2 7/8	9	6·491	2 9/16

Dia. in inch.	Cir. in ft.	in.	Area in sq. inch.	Ar. in sq. ft.
3 in.		9 3/8	7·068	2 5/8
3 1/8		9 3/4	7·669	2 3/4
3 1/4		10 1/4	8·295	2 7/8
3 3/8		10 5/8	8·946	3 in.
3 1/2		11	9·621	3 1/8
3 5/8		11 3/8	10·320	3 1/4
3 3/4		11 3/4	11·044	3 3/8
3 7/8		12 1/8	11·793	3 7/16
4 in.	1	0 1/2	12·566	·0879
4 1/8	1	0 7/8	13·364	·0935
4 1/4	1	1 3/8	14·186	·0993
4 3/8	1	1 3/4	15·033	·1052
4 1/2	1	2 1/8	15·904	·1113
4 5/8	1	2 1/2	16·800	·1176
4 3/4	1	2 7/8	17·720	·1240
4 7/8	1	3 1/4	18·665	·1306
5 in.	1	3 5/8	19·635	·1374
5 1/8	1	4 1/8	20·629	·1444
5 1/4	1	4 1/2	21·647	·1515
5 3/8	1	4 7/8	22·690	·1588
5 1/2	1	5 1/4	23·758	·1663
5 5/8	1	5 5/8	24·850	·1739
5 3/4	1	6	25·967	·1817
5 7/8	1	6 3/8	27·108	·1897
6 in.	1	6 3/4	28·274	·1979
6 1/8	1	7 1/4	29·464	·2062
6 1/4	1	7 5/8	30·679	·2147
6 3/8	1	8	31·919	·2234
6 1/2	1	8 3/8	33·183	·2322
6 5/8	1	8 3/4	34·471	·2412
6 3/4	1	9 1/8	35·784	·2504
6 7/8	1	9 1/2	37·122	·2598
7 in.	1	10	38·484	·2693
7 1/8	1	10 3/8	39·871	·2791
7 1/4	1	10 3/4	41·282	·2889
7 3/8	1	11 1/8	42·718	·2990
7 1/2	1	11 1/2	44·178	·3092
7 5/8	1	11 7/8	45·663	·3196
7 3/4	2	0 3/8	47·173	·3299
7 7/8	2	0 3/4	48·707	·3409

Dia. in inch.	Cir. in ft.	Cir. in in.	Area in sq. inch.	Area in sq. ft.	Dia. in inch.	Cir. in ft.	Cir. in in.	Area in sq. inch.	Area in sq. ft.
8 in.	2	1⅛	50·265	·3518	13 in.	3	4¾	132·732	·9291
8⅛	2	1½	51·848	·3629	13⅛	3	5¼	135·297	·9470
8¼	2	1⅞	53·456	·3741	13¼	3	5⅝	137·886	·9642
8⅜	2	2¼	55·088	·3856	13⅜	3	6	140·500	·9835
8½	2	2⅝	56·745	·3972	13½	3	6⅜	143·139	1·0019
8⅝	2	3	58·426	·4089	13⅝	3	6¾	145·802	1·0206
8¾	2	3⅜	60·132	·4209	13¾	3	7⅛	148·489	1·0294
8⅞	2	3⅞	61·862	·4330	13⅞	3	7½	151·201	1·0584
9 in.	2	4¼	63·617	·4453	14 in.	3	7⅞	153·938	1·0775
9⅛	2	4⅝	65·396	·4577	14⅛	3	8⅜	156·699	1·0968
9¼	2	5	67·200	·4704	14¼	3	8¾	159·485	1·1193
9⅜	2	5⅜	69·029	·4832	14⅜	3	9⅛	162·295	1·1360
9½	2	5¾	70·882	·4961	14½	3	9½	165·130	1·1569
9⅝	2	6¼	72·759	·5093	14⅝	3	9⅞	167·989	1·1749
9¾	2	6⅝	74·662	·5226	14¾	3	10¼	170·873	1·1961
9⅞	2	7	76·588	·5361	14⅞	3	10¾	173·782	1·2164
10 in.	2	7⅜	78·540	·5497	15 in.	3	11⅛	176·715	1·2370
10⅛	2	7¾	80·515	·5636	15⅛	3	11½	179·672	1·2577
10¼	2	8⅛	82·516	·5776	15¼	3	11⅞	182·654	1·2785
10⅜	2	8½	84·540	·5917	15⅜	4	0¼	185·661	1·2996
10½	2	8⅞	86·590	·6061	15½	4	0⅝	188·692	1·3208
10⅝	2	9⅜	88·664	·6206	15⅝	4	1	191·748	1·3422
10¾	2	9¾	90·762	·6353	15¾	4	1½	194·828	1·3637
10⅞	2	10⅛	92·855	·6499	15⅞	4	1⅞	197·933	1·3855
11 in.	2	10½	95·033	·6652	16 in.	4	2¼	201·062	1·4074
11⅛	2	10⅞	97·205	·6804	16⅛	4	2⅝	204·216	1·4295
11¼	2	11¼	99·402	·6958	16¼	4	3	207·394	1·4517
11⅜	2	11¾	101·623	·7143	16⅜	4	3⅜	210·597	1·4741
11½	3	0⅛	103·869	·7270	16½	4	3¾	213·825	1·4967
11⅝	3	0½	106·139	·7429	16⅝	4	4¼	217·077	1·5195
11¾	3	0⅞	108·434	·7590	16¾	4	4⅝	220·353	1·5424
11⅞	3	1¼	110·753	·7752	16⅞	4	5	223·054	1·5655
12 in.	3	1⅝	113·097	·7916	17 in.	4	5⅜	226·980	1·5888
12⅛	3	2	115·466	·8082	17⅛	4	5¾	230·330	1·6123
12¼	3	2½	117·859	·8250	17¼	4	6⅛	233·705	1·6359
12⅜	3	2⅞	120·276	·8419	17⅜	4	6½	237·104	1·6597
12½	3	3¼	122·718	·8590	17½	4	6⅞	240·528	1·6836
12⅝	3	3⅝	125·185	·8762	17⅝	4	7⅜	243·977	1·7078
12¾	3	4	127·676	·8937	17¾	4	7¾	247·450	1·7321
12⅞	3	4⅜	130·192	·9113	17⅞	4	8⅛	250·947	1·7566

Dia. in inch.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.	Dia. in inch.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.
18	4 8½	254·469	1·7812	23	6 0¼	415·476	2·8903
18⅛	4 8⅞	258·016	1·8061	23⅛	6 0⅝	420·004	2·9100
18¼	4 9¼	261·587	1·8311	23¼	6 1	424·557	2·9518
18⅜	4 9¾	265·182	1·8562	23⅜	6 1⅜	429·135	2 9937
18½	4 10⅛	268·803	1·8816	23½	6 1¾	433·737	3·0129
18⅝	4 10½	272·447	1·9071	23⅝	6 2¼	438·363	3·0261
18¾	4 10⅞	276·117	1·9328	23¾	6 2⅝	443·014	3·0722
18⅞	4 11¼	279·811	1:9586	23⅞	6 3	447·690	3·1081
19	4 11⅝	283·529	1·9847	2 0	6 3⅜	452·390	3·1418
19⅛	5 0	287·272	1·9941	2 0¼	6 4⅛	461·864	3·2075
19¼	5 0½	291·039	2·0371	2 0½	6 4⅞	471·436	3·2731
19⅜	5 0⅞	294·831	2·0637	2 0¾	6 5¾	481·106	3·3410
19½	5 1¼	298·648	2·0904	2 1	6 6½	490·875	3·4081
19⅝	5 1⅝	302·489	2·1172	2 1¼	6 7¼	500·741	3·4775
19¾	5 2	306·355	2·1443	2 1½	6 8⅛	510·706	3·5468
19⅞	5 2⅜	310·245	2·1716	2 1¾	6 8⅞	520·769	3·6101
20	5 2⅞	314·160	2·1990	2 2	6 9⅝	530·930	3·6870
20⅛	5 3¼	318 099	2·2265	2 2¼	6 10½	541·189	3·7583
20¼	5 3⅝	322·063	2·2543	2 2½	6 11¼	551·547	3·8302
20⅜	5 4	326·0[illegible]1	2·2822	2 2¾	7 0	562·002	3·9042
20½	5 4⅜	330·0[illegible]4	2·3103	2 3	7 0⅞	572·556	3·9761
20⅝	5 4¾	334·101	2·3386	2 3¼	7 1⅝	583·208	4·0500
20¾	5 5⅛	338·163	2·3670	2 3½	7 2⅜	593·958	4·1241
20⅞	5 5½	342·250	2·3956	2 3¾	7 3⅛	604·807	4·2000
21	5 5⅞	346·361	2·4244	2 4	7 3⅞	615·753	4·2760
21⅛	5 6⅜	350·497	2·4533	2 4¼	7 4¾	626·798	4·3521
21¼	5 6¾	354·657	2·4824	2 4½	7 5½	637·941	4·4302
21⅜	5 7⅛	358·841	2·5117	2 4¾	7 6¼	649·182	4·5083
21½	5 7½	363·051	2·5412	2 5	7 7	660·521	4·5861
21⅝	5 7⅞	367·284	2·5708	2 5¼	7 7⅞	671·958	4·6665
21¾	5 8¼	371·543	2·6007	2 5½	7 8⅝	683·494	4·7467
21⅞	5 8¾	375·826	2·6306	2 5¾	7 9½	695·128	4·8274
22	5 9⅛	380·133	2·6608	2 6	7 10¼	706·860	4·9081
22⅛	5 9½	384·465	2·6691	2 6¼	7 11	718·690	4·9901
22¼	5 9⅞	388·822	2·7016	2 6½	7 11¾	730·618	5·0731
22⅜	5 10¼	393·203	2·7224	2 6¾	8 0⅝	742·644	5·1573
22½	5 10⅝	397·608	2·7632	2 7	8 1⅜	754·769	5·2278
22⅝	5 11	402·038	2·7980	2 7¼	8 2⅛	766·992	5·3264
22¾	5 11½	406·493	2·8054	2 7½	8 2⅞	779·313	5·4112
22⅞	5 11⅞	410·972	2·8658	2 7¾	8 3¾	791·732	5·4982

Dia. in ft. in.	Cir. in ft. in.	Area in sq. inch.	Area in sq. ft.	Dia. in ft. in.	Cir. in ft. in.	Area in sq. in.	Area in sq. ft.
2 8	8 4½	804·249	5·5850	3 6	10 11⅞	1385·44	9·6212
2 8¼	8 5⅜	816·865	5·6729	3 6¼	11 0¾	1401·98	9·7364
2 8½	8 6⅛	829·578	5·7601	3 6½	11 1½	1418·62	9·8518
2 8¾	8 6⅞	842·390	5·8491	3 6¾	11 2¼	1435·36	9·9671
2 9	8 7⅝	855·300	5·9398	3 7	11 3	1452·20	10·084
2 9¼	8 8½	868·308	6·0291	3 7¼	11 3⅞	1469·14	10·202
2 9½	8 9¼	881·415	6·1201	3 7½	11 4⅝	1486·17	10·320
2 9¾	8 10	894·619	6·2129	3 7¾	11 5⅜	1503·30	10·439
2 10	8 10¾	907·922	6·3051	3 8	11 6¼	1520·53	10·559
2 10¼	8 11½	921·323	6·3981	3 8¼	11 7	1537·86	10·679
2 10½	9 0⅜	934·822	6·4911	3 8½	11 7¾	1555·28	10·800
2 10¾	9 1⅛	948·419	6·5863	3 8¾	11 8½	1572·81	10·922
2 11	9 1⅞	962·115	6·6815	3 9	11 9⅜	1590·43	11·044
2 11¼	9 2¾	975·908	6·7772	3 9¼	11 10⅛	1608·15	11·167
2 11½	9 3½	989·800	6·8738	3 9½	11 10⅞	1625·97	11·291
2 11¾	9 4¼	1003·79	6·9701	3 9¾	11 11¾	1643·89	11·415
3 0	9 5	1017·87	7·0688	3 10	12 0½	1661·90	11·534
3 0¼	9 5⅞	1032·06	7·1671	3 10¼	12 1¼	1680·02	11·666
3 0½	9 6⅝	1046·35	7·2664	3 10½	12 2	1698·23	11·793
3 0¾	9 7½	1060·73	7·3662	3 10¾	12 2⅞	1716·54	11·920
3 1	9 8¼	1075·21	7·4661	3 11	12 3⅝	1734·94	12·048
3 1¼	9 9	1089·79	7·5671	3 11¼	12 4⅜	1753·45	12·176
3 1½	9 9⅞	1104·46	7·6691	3 11½	12 5¼	1772·05	12·305
3 1¾	9 10½	1119·24	7·7791	3 11¾	12 6	1790·76	12·435
3 2	9 11⅜	1134·12	7·8681	4 0	12 6¾	1809·56	12·566
3 2¼	10 0⅛	1149·09	7·9791	4 0¼	12 7½	1828·46	12·697
3 2½	10 0⅞	1164·16	8·0846	4 0½	12 8⅜	1847·45	12·829
3 2¾	10 1¾	1179·32	8·1891	4 0¾	12 9⅛	1866·55	12·962
3 3	10 2½	1194·59	8·2951	4 1	12 9⅞	1885·74	13·095
3 3¼	10 3¼	1209·95	8·4026	4 1¼	12 10¾	1905·03	13·229
3 3½	10 4	1225·42	8·5091	4 1½	12 11½	1924·42	13·364
3 3¾	10 4⅞	1240·98	8·6171	4 1¾	13 0¼	1943·91	13·499
3 4	10 5⅝	1256·64	8·7269	4 2	13 1	1963·50	13·635
3 4¼	10 6⅜	1272·39	8·8361	4 2¼	13 1⅞	1983·18	13·772
3 4½	10 7¼	1288·25	8·9462	4 2½	13 2⅝	2002·96	13·909
3 4¾	10 8	1304·20	9·0561	4 2¾	13 3⅜	2022·84	14·047
3 5	10 8¾	1320·25	9·1686	4 3	13 4¼	2042·82	14·186
3 5¼	10 9½	1336·40	9·2112	4 3¼	13 5	2062·90	14·325
3 5½	10 10⅜	1352·65	9·3936	4 3½	13 5¾	2083·07	14·465
3 5¾	10 11⅛	1369·00	9·5061	4 3¾	13 6½	2103·35	14·606

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4	4	13	7⅜	2123·72	14·748
4	4¼	13	8⅛	2144·19	14·890
4	4½	13	8⅞	2164·75	15·033
4	4¾	13	9¾	2185·42	15·176
4	5	13	10½	2206·18	15·320
4	5¼	13	11¼	2227·05	15·465
4	5½	14	0	2248·01	15·611
4	5¾	14	0⅞	2269·06	15·757
4	6	14	1⅝	2290·22	15·904
4	6¼	14	2⅜	2311·48	16·051
4	6½	14	3¼	2332·83	16·200
4	6¾	14	4	2354·28	16·349
4	7	14	4¾	2375·83	16·498
4	7¼	14	5½	2397·48	16·649
4	7½	14	6⅜	2419·22	16·800
4	7¾	14	7⅛	2441·07	16·951
4	8	14	7⅞	2463·01	17·104
4	8¼	14	8⅝	2485·05	17·257
4	8½	14	9½	2507·19	17·411
4	8¾	14	10¼	2529·42	17·565
4	9	14	11	2551·76	17·720
4	9¼	14	11⅞	2574·19	17·876
4	9½	15	0⅝	2596·72	18·033
4	9¾	15	1⅜	2619·35	18·189
4	10	15	2¼	2642·08	18·347
4	10¼	15	2⅞	2664·91	18·506
4	10½	15	3¾	2687·83	18·665
4	10¾	15	4½	2710·85	18·825
4	11	15	5¼	2733·97	18·985
4	11¼	15	6⅛	2757·19	19·147
4	11½	15	6⅞	2780·51	19·309
4	11¾	15	7¾	2803·92	19·471
5	0	15	8½	2827·44	19·635
5	0¼	15	9¼	2851·05	19·798
5	0½	15	10	2874·76	19·963
5	0¾	15	10¾	2898·56	20·128
5	1	15	11⅝	2922·47	20·294
5	1¼	16	0⅜	2946·47	20·461
5	1½	16	1¼	2970·57	20·629
5	1¾	16	1⅞	2994·77	20·797
5	2	16	2¾	3019·07	20·965
5	2¼	16	3½	3043·47	21·135
5	2½	16	4¼	3067·96	21·305
5	2¾	16	5⅛	3092·56	21·476
5	3	16	5⅞	3117·25	21·647
5	3¼	16	6¼	3142·04	21·819
5	3½	16	7½	3166·92	21·992
5	3¾	16	8¼	3191·91	22·166
5	4	16	9	3216·99	22·333
5	4¼	16	9¾	3242·17	22·515
5	4½	16	10⅝	3267·46	22·621
5	4¾	16	11⅜	3292·83	22·866
5	5	17	0⅛	3318·31	23·043
5	5¼	17	0⅞	3343·88	23·221
5	5½	17	1¾	3369·56	23·330
5	5¾	17	2½	3395·33	23·578
5	6	17	3⅜	3421·20	23·758
5	6¼	17	4⅛	3447·16	23·938
5	6½	17	4⅞	3473·23	24·119
5	6¾	17	5⅝	3499·39	24·301
5	7	17	6½	3525·66	24·483
5	7¼	17	7¼	3552·01	24·666
5	7½	17	8	3578·47	24·850
5	7¾	17	8¾	3605·03	25·034
5	8	17	9⅝	3631·68	25·220
5	8¼	17	10⅜	3658·44	25·405
5	8½	17	11⅛	3685·29	25·592
5	8¾	17	11⅞	3712·24	25·779
5	9	18	0¾	3739·28	25·964
5	9¼	18	1½	3766·43	26·155
5	9½	18	2¼	3793·67	26·344
5	9¾	18	3⅛	3821·02	26·534
5	10	18	3⅞	3848·46	26·725
5	10¼	18	4⅝	3875·99	26·916
5	10½	18	5½	3903·63	27·108
5	10¾	18	6¼	3931·36	27·301
5	11	18	7	3959·20	27·494
5	11¼	18	7¾	3987·13	27·688
5	11½	18	8⅝	4015·16	27·883
5	11¾	18	9⅜	4043·28	28·078

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6	0	18	10⅛	4071·51	28·274	6	6	20	5	4778·37	33·183
6	0¼	18	10⅞	4099·83	28·471	6	6¼	20	5¾	4809·05	33·396
6	0½	18	11¾	4128·25	28·663	6	6½	20	6½	4839·83	33·619
6	0¾	19	0½	4156·77	28·866	6	6¾	20	7⅜	4870·70	33·824
6	1	19	1¼	4185·39	29·065	6	7	20	8⅛	4901·68	34·039
6	1¼	19	2⅛	4214·11	29·264	6	7¼	20	8⅞	4932·75	34·255
6	1½	19	2⅞	4242·92	29·466	6	7½	20	9¾	4963·92	34·471
6	1¾	19	3⅝	4271·83	29·665	6	7¾	20	10½	4995·19	34·688
6	2	19	4½	4300·85	29·867	6	8	20	11¼	5026·26	34·906
6	2¼	19	5¼	4329·95	30·069	6	8¼	21	0⅛	5058·02	35·125
6	2½	19	6	4359·16	30·271	6	8½	21	0⅞	5089·58	35·344
6	2¾	19	6¾	4388 47	30·475	6	8¾	21	1⅝	5121·24	35·564
6	3	19	7⅝	4417·87	30·679	6	9	21	2⅜	5153·00	35·784
6	3¼	19	8⅜	4447·37	30·884	6	9¼	21	3¼	5184·86	36·006
6	3½	19	9⅕	4476·97	31·090	6	9½	21	4	5216·82	36·227
6	3¾	19	9⅞	4506·67	31·296	6	9¾	21	4¾	5248·87	36·450
6	4	19	10¾	4536·47	31·503	6	10	21	5½	5281·02	36·674
6	4¼	19	11½	4566·36	31·710	6	10¼	21	6⅜	5313·27	36·897
6	4½	20	0¼	4596·35	31·919	6	10½	21	7⅛	5345·62	37·122
6	4¾	20	1⅛	4626·44	32·114	6	10¾	21	7⅞	5378·07	37·347
6	5	20	1⅞	4656·63	32·337	6	11	21	8¾	5410·62	37·573
6	5¼	20	2⅝	4686·92	32·548	6	11¼	21	9½	5443·26	37·700
6	5½	20	3½	4717·30	32·759	6	11½	21	10¼	5476·00	38·027
6	5¾	20	4¼	4747·79	32·970	6	11¾	21	11	5508·84	38·256

Diam. in ft. and in.		Circum. in ft. and in.		Area in feet.
7	0	21	11⅞	38·4846
	1	22	3	39·4060
	2	22	6⅛	40·3388
	3	22	9¼	41·2825
	4	23	0⅜	42·2367
	5	23	2⅛	43·2022
	6	23	6¾	44·1787
	7	23	11	45·1656
	8	24	1⅛	46·1638
	9	24	4⅛	47·1730
	10	24	7¼	48·1926
	11	24	10⅜	49·2236
8	0	25	1½	50·2656
	1	25	4⅝	51·3178
	2	25	7⅞	52·3816
	3	25	11	53·4562
	4	26	2⅛	54·5412
	5	26	5¼	55·6377
	6	26	8⅜	56·7451
	7	26	11½	57·8628
	8	27	2¾	58·9920
	9	27	5¾	60·1321
	10	27	9	61·2826
	11	28	0⅛	62·4445
9	0	28	3¼	63·6174
	1	28	6⅜	64·8006
	2	28	9½	65·9951
	3	29	0⅝	67·2007
	4	29	3¾	68·4166
	5	29	7	69·6440
	6	29	10⅛	70·8823
	7	30	1¼	72·1309
	8	30	4⅜	73·3910
	9	30	7½	74·6620
	10	30	11⅝	75·9433
	11	31	1¾	77·2362
10	0	31	5	78·5400
	1	31	8⅛	79·8540
	2	31	11¼	81·1795
	3	32	2⅜	82·5160
	4	32	5½	83·8627
	5	32	8⅝	85·[illegible]
	6	32	11¾	86·[illegible]
	7	33	2⅞	87·9697
	8	33	6⅛	89·3608
	9	33	9¼	90·7627
	10	34	0⅜	92·1749
	11	34	3½	93·5986
11	0	34	6⅝	95·0334
	1	34	9¾	96·4783
	2	35	0⅞	97·9347
	3	35	4⅛	99·4021
	4	35	7¼	100·8797
	5	35	10⅝	102·3689
	6	36	1½	103·8691
	7	36	4½	105·3794
	8	36	7¾	106·9013
	9	36	10⅞	108·4342
	10	37	2¾	109·9772
	11	37	5¼	111·5319
12	0	37	8⅜	113·0976
	1	37	11½	114·6732
	2	38	2⅝	116·2607
	3	38	5¾	117·8590
	4	38	8⅞	119·4674
	5	39	0	121·0876
	6	39	3¼	122·7187
	7	39	6⅜	124·3598
	8	39	9½	126·0127
	9	40	0⅝	127·6765
	10	40	3¾	129·3504
	11	40	6⅞	131·0360

Diam. in ft. and in.		Circum. in ft. and in.		Area in feet.	Diam. in ft. and in.		Circum. in ft. and in.		Area in feet.
13	0	40	10	132·7326	16	0	50	3⅛	201·0624
	1	41	1⅛	134·4391		1	50	6¼	203·1615
	2	41	4⅜	136·1574		2	50	9⅜	205·2726
	3	41	7½	137·8867		3	51	0½	207·3946
	4	41	10⅝	139·6260		4	51	3¾	209·5264
	5	42	1⅝	141·3771		5	51	6½	211·6703
	6	42	4⅞	143·1391		6	51	10	213·8251
	7	42	8	144·9111		7	52	1⅛	215·9896
	8	42	11⅛	146·6949		8	52	4¼	218·1662
	9	43	2¼	148·4896		9	52	7⅜	220·3537
	10	43	5½	150·2943		10	52	10½	222·5510
	11	43	8⅝	152·1109		11	53	1⅝	224·7603
14	0	43	11¾	153·9384	17	0	53	4⅞	226·9806
	1	44	2⅞	155·7758		1	53	8	229·2105
	2	44	6	157·6250		2	53	11⅛	231·4625
	3	44	9⅛	159·4852		3	54	2⅛	233·7055
	4	45	0¼	161·3553		4	54	5⅜	235·9682
	5	45	3½	163·2373		5	54	8½	238·2430
	6	45	6⅝	165·1303		6	54	11⅝	240·5287
	7	45	9¾	167·0331		7	55	2⅞	242·8241
	8	46	0⅞	168·9479		8	55	6	245·1316
	9	46	4	170·8735		9	55	9⅛	247·4500
	10	46	7⅛	172·8091		10	56	0¼	249·7781
	11	46	11¼	174·7565		11	56	3½	252·1184
15	0	47	1½	176·7150	18	0	56	6½	254·4696
	1	47	4⅝	178·6832		1	56	9⅝	256·8303
	2	47	7¾	180·6634		2	57	0⅞	259·2033
	3	47	10⅞	182·6545		3	57	4	261·5872
	4	48	2½	184·6555		4	57	7⅛	263·9807
	5	48	5⅛	186·6684		5	57	10¼	266·3864
	6	48	8¼	188·6923		6	58	1⅜	268·8031
	7	48	11⅜	190·7260		7	58	4½	271·2293
	8	49	2⅝	192·7716		8	58	7⅝	273·6678
	9	49	5¾	194·8282		9	58	10¾	276·1171
	10	49	8⅞	196·8946		10	59	2	278·5761
	11	50	0	198·9730		11	59	5⅛	281·0472

No.	S. R.	C. R.	No.	S. R.	C. R.	No.	S. R.	C. R.	No.	S. R.	C. R.
1	1·0000	1·0000	55	7·4161	3·8029	109	10·4403	4·7768	163	12·7671	5·4625
2	1·4142	1·2599	56	7·4833	3·8258	110	10·4880	4·7914	164	12·8062	5·4737
3	1·7320	1·4422	57	7·5498	3·8485	111	10·5356	4·8058	165	12·8452	5·4848
4	2·0000	1·5874	58	7·6157	3·8708	112	10·5830	4·8202	166	12·8840	5·4958
5	2·2360	1·7099	59	7·6811	3·8929	113	10·6301	4·8345	167	12·9228	5·5068
6	2·4494	1·8171	60	7·7459	3·9148	114	10·6770	4·8488	168	12·9614	5·5178
7	2·6457	1·9129	61	7·8102	3·9364	115	10·7238	4·8629	169	13·0000	5·5287
8	2·8284	2·0000	62	7·8740	3·9578	116	10·7703	4·8769	170	13·0384	5·5396
9	3·0000	2·0800	63	7·9372	3·9790	117	10·8166	4·8909	171	13·0766	5·5404
10	3·1622	2·1544	64	8·0000	4·0000	118	10·8627	4·9048	172	13·1148	5·5612
11	3·3166	2·2239	65	8·0622	4·0207	119	10·9087	4·9186	173	13·1529	5·5720
12	3·4641	2·2894	66	8·1240	4·0412	120	10·9544	4·9324	174	13·1909	5·5827
13	3·6055	2·3513	67	8·1853	4·0615	121	11·0000	4·9460	175	13·2287	5·5934
14	3·7416	2·4101	68	8·2462	4·0816	122	11·0153	4·9596	176	13·2664	5·6040
15	3·8729	2·4662	69	8·3066	4·1015	123	11·0905	4·9731	177	13·3041	5·6416
16	4·0000	2·5198	70	8·3666	4·1212	124	11·1355	4·9866	178	13·3416	5·6252
17	4·1231	2·5712	71	8·4261	4·1408	125	11·1803	5·0000	179	13·3790	5·6357
18	4·2426	2·6207	72	8·4852	4·1601	126	11·2249	5·0132	180	13·4164	5·6462
19	4·3588	2·6684	73	8·5440	4·1793	127	11·2694	5·0265	181	13·4536	5·6566
20	4·4721	2·7144	74	8·6023	4·1983	128	11·3137	5·0396	182	13·4907	5·6670
21	4·5825	2·7589	75	8·6602	4·2171	129	11·3578	5·0527	183	13·5277	5·6774
22	4·6904	2·8020	76	8·7177	4·2358	130	11·4017	5·0657	184	13·5646	5·6877
23	4·7958	2·8438	77	8·7749	4·2543	131	11·4455	5·0787	185	13·6014	5·6980
24	4·8989	2·8844	78	8·8317	4·2726	132	11·4891	5·0916	186	13·6381	5·7082
25	5·0000	2·9240	79	8·8881	4·2908	133	11·5325	5·1044	187	13·6747	5·7184
26	5·0990	2·9624	80	8·9442	4·3088	134	11·5758	5·1172	188	13·7113	5·7286
27	5·1961	3·0000	81	9·0000	4·3267	135	11·6189	5·1299	189	13·7477	5·7387
28	5·2915	3·0365	82	9·0553	4·3444	136	11·6619	5·1425	190	13·7840	5·7488
29	5·3851	3·0723	83	9·1104	4·3620	137	11·7046	5·1551	191	13·8202	5·7589
30	5·4772	3·1072	84	9·1651	4·3795	138	11·7473	5·1676	192	13·8564	5·7689
31	5·5677	3·1413	85	9·2195	4·3968	139	11·7898	5·1801	193	13·8924	5·7789
32	5·6568	3·1748	86	9·2736	4·4140	140	11·8321	5·1924	194	13·9283	5·7889
33	5·7445	3·2075	87	9·3273	4·4310	141	11·8743	5·2048	195	13·9642	5·7988
34	5·8309	3·2396	88	9·3808	4·4479	142	11·9163	5·2171	196	14·0000	5·8087
35	5·9160	3·2710	89	9·4339	4·4647	143	11·9582	5·2293	197	14·0356	5·8186
36	6·0000	3·3019	90	9·4868	4·4814	144	12·0000	5·2414	198	14·0712	5·8284
37	6·0827	3·3322	91	9·5393	4·4979	145	12·0415	5·2535	199	14·1067	5·8382
38	6·1644	3·3619	92	9·5916	4·5143	146	12·0830	5·2656	200	14·1421	5·8480
39	6·2449	3·3912	93	9·6436	4·5306	147	12·1243	5·2776	201	14·1774	5·8577
40	6·3245	3·4199	94	9·6953	4·5468	148	12·1655	5·2895	202	14·2126	5·8674
41	6·4031	3·4482	95	9·7467	4·5629	149	12·2065	5·3014	203	14·2478	5·8771
42	6·4807	3·4760	96	9·7979	4·5788	150	12·2474	5·3132	204	14·2828	5·8867
43	6·5574	3·5033	97	9·8488	4·5947	151	12·2882	5·3250	205	14·3178	5·8963
44	6·6332	3·5303	98	9·8994	4·6104	152	12·3288	5·3368	206	14·3527	5·9059
45	6·7082	3·5568	99	9·9498	4·6260	153	12·3693	5·3484	207	14·3874	5·9154
46	6·7823	3·5830	100	10·0000	4·6415	154	12·4096	5·3601	208	14·4222	5·9249
47	6·8556	3·6088	101	10·0198	4·6570	155	12·4498	5·3716	209	14·4568	5·9344
48	6·9282	3·6342	102	10·0995	4·6723	156	12·4899	5·3832	210	14·4913	5·9439
49	7·0000	3·6593	103	10·1488	4·6875	157	12·5299	5·3946	211	14·5258	5·9533
50	7·0710	3·6840	104	10·1980	4·7026	158	12·5698	5·4061	212	14·5602	5·9627
51	7·1414	3·7084	105	10·2469	4·7176	159	12·6095	5·4175	213	14·5945	5·9720
52	7·2111	3·7325	106	10·2956	4·7326	160	12·6491	5·4288	214	14·6287	5·9814
53	7·2801	3·7563	107	10·3440	4·7474	161	12·6885	5·4401	215	14·6628	5·9907
54	7·3484	3·7797	108	10·3923	4·7622	162	12·7279	5·4513	216	14·6969	6·0000

To find the square or cube root of a number consisting of integers and decimals.

Rule.—Multiply the difference between the root of the integer part of the given number, and the root of the next higher number, by the decimal part of the given number, and add the product to the root of the given integer number; the sum is the root required.

Ex. Required the square root of 20·321.

Square root of 21 = 4·5825
" " " 20 = 4·4721
Diff. = ·1104 × ·321 + 4·4721 = 4·507, &c., the root required.

MISCELLANEOUS NOTES

VARNISHES.

[From Dr. Ure's Dictionary of Arts and Manufactures.]

White Spirit Varnish.— Sandarach, 250 parts; mastic in tears, 64; elemi resin, 32; Venice turpentine, 64; alcohol of 85 per cent., 1000 parts by measure The turpentine is to be added after the resins are dissolved. This is a brilliant varnish, but not so hard as to bear polishing.

Varnish for the Wood Toys of Spa.— Tender copal, 75 parts; mastic, 12·5; Venice turpentine, 6·5; alcohol of 95 per cent., 100 parts by measure; water, ounces — for example, if the other be taken in ounces. The alcohol must be first made to act upon the copal, with the aid of a little oil of lavender or camphor, if thought fit; and, the solution being passed through a linen cloth, the mastic must be introduced. After it is dissolved, the Venice turpentine, previously melted in a water bath, should be added. The lower the temperature at which these operations are carried on, the more beautiful will the varnish be. This varnish ought to be very white, very drying, and capable of being smoothed with pumice-stone and polished.

Varnish for Cabinet-Makers.— Pale shellac, 750 parts; mastic, 64; alcohol of 90 per cent., 1000 parts by measure. The solution is made in the cold, with the aid of frequent stirring. It is always muddy, and is employed without being filtered. With the same resins and proof spirit, a varnish is made for the bookbinders, to do over their morocco leather.

Crystal Varnish.— Procure a bottle of Canada balsam, which can be had at any druggist's; draw out the cork and set the bottle of balsam at a little distance

from the fire, turning it round several times, until the heat has thinned it; then have something that will hold as much as double the quantity of balsam; carry the balsam from the fire, and, while fluid, mix it with the same quantity of good turpentine, and shake them together until they are well incorporated. In a few days, the varnish is fit for use; particularly if it is poured into a half-gallon glass or stone bottle, and kept in a gentle warmth. This varnish is used for maps, prints, charts, drawings, paper ornaments, &c.

The Chinese Varnish is obtained from a tree which grows in Cochin-China, China, and Siam. It forms the best of all varnishes.

Gold Lacker. — Put into a clean four-gallon tin 1 lb. ground turmeric, 1½ oz. powdered gamboge, 3½ lbs. powdered gum sandarach, ¾ lb. shellac, and 2 galls. spirits of wine. After being dissolved and strained, add 1 pint of turpentine varnish, well mixed.

Red Spirit Lacker. — 2 galls. spirits of wine; 1 lb. dragon's-blood; 3 lbs. Spanish annotto; 3½ lbs. gum sandarach; 2 pints turpentine; — made exactly as the gold lacker.

The Varnish of Watin, for Gilded Articles. — Gum lac in grain, 125 parts; gamboge, 125; dragon's-blood, 125; annotto, 125; saffron, 32. Each resin must be dissolved in 1000 parts by measure of alcohol of 90 per cent. Two separate tinctures must be made with the dragon's-blood and annotto, in 1000 parts of such alcohol; and a proper proportion of each should be added to the varnish, according to the shade of golden color wanted.

Transfer Varnish. — For fixing engravings or lithographs upon wood, a varnish called *mordant* is used in France, which differs from others chiefly in containing more Venice turpentine, to make it sticky. It consists of sandarach, 250 parts; mastic in tears, 64; rosin, 125; Venice turpentine, 250; alcohol, 1000 parts by measure.

Common Mastic Varnish. — Put as much gum mastic,

unpicked, into the gum-pot, as may be required; and to every 2¾ lbs. of gum, pour in 1 gall. of cold turpentine; set the pot over a very moderate fire, and stir it. Be careful, when the steam of the turpentine rises near the mouth of the pot, to cover with a piece of woollen cloth, and carry it out of doors, as the vapor is very apt to catch fire. A few minutes' low heat will perfectly dissolve 8 lbs. of gum, which will, with 4 galls. of turpentine, produce, when strained, 4½ galls. of varnish; to which add, while yet hot, 5 pints of pale turpentine varnish, which improves the body and hardness of the mastic varnish.

Pale Brass Lacker.—2 galls. spirits of wine; 3 oz. Cape aloes; cut small 1 lb. fine pale shellac; 1 oz. gamboge, cut small; no turpentine;—varnish made exactly as before. But observe, that those who make lackers frequently want some paler and some darker; and sometimes inclining more to the particular tint of certain of the component ingredients. Therefore, if a 4 oz. phial of a strong solution of each ingredient be prepared, a lacker of any tint can be produced at any time.

Iron-Work Black.—Put 48 lbs. asphaltum into an iron pot, and boil for 4 hours; during the first 2 hours, introduce 7 lbs. litharge, 3 lbs. dried copperas, and 10 galls. boiled; add 1-eighth lb. run of dark gum, with 2 galls. hot oil. After pouring the oil and gum, continue the boiling 2 hours, or until it will roll into hard pills, like Japan. When cool, thin it off with 30 galls. turpentine, or until it is of proper consistence. This varnish is intended for the iron-work of coaches and other carriages, &c.

To make Cloth, Silk, &c. water-proof.—Mix equal quantities of alum and acetate of lead, and dissolve the mixture in a gallon and a half of boiling water. When the solution has cooled, remove the supernatant liquid from the sediment, which consists of sulphate of lead, and it is ready for use. Any article of dress, when well saturated in this liquid, and allowed to dry

slowly, bears the action of boiling water, and does not permit it to pass through, although steam and air penetrate it freely.

Cement for China, Glass, &c. — To 1 oz. gum mastic add as much spirits of wine as will dissolve it; soak 1 oz. isinglass in water till it is quite soft, then dissolve it in pure brandy till of the consistence of glue; to this add ¼ oz. gum ammoniac, well rubbed and mixed. Put now the two mixtures together in a vessel over a gentle heat, till properly united, and the cement is ready for use. It must be kept in a phial well stopped; and, when about to be used, it ought to be set in boiling water to soften.

Preparation for Silver Solution. — Take 1 pint of pure rain or distilled water; add to it 2 oz. cyanide of potassium; shake them together occasionally, until the latter is entirely dissolved, and allow the liquid to become clear; then add ¼ oz. oxide of silver, which will very speedily dissolve; and, after a short time, a clear, transparent solution will be obtained.

Preparation of Gold Solution. — Warm a pint of pure rain water, and dissolve in it 2 oz. cyanide of potassium; then add ¼ oz. oxide of gold; the solution will at first be yellowish, but will soon subside to white.

SOLDERS.

For Lead. — Melt 1 part of block tin, and, when in a state of fusion, add 2 parts of lead. Resin should be used with this solder.

For Tin. — Pewter, 4 parts; tin, 1; bismuth, 1; melt them together. Resin is also used with this solder.

For Iron. — Tough brass, with a small quantity of borax.

CAPACITY OF CISTERNS IN GALLONS.

For each 10 Inches in Depth.

2 feet diameter, . .	19·5	8 feet diameter, .	313·33
2½ " " . .	30·6	8½ " " . .	353·72
3 " " . .	44·06	9 " " . .	396·56
3½ " " . .	59·97	9½ " " . .	461·40
4 " " . .	78·33	10 " " . .	489·20
4½ " " . .	99·14	11 " " . .	592·40
5 " " . .	122·40	12 " " . .	705·
5½ " " . .	148·10	13 " " . .	827·4
6 " " . .	176·25	14 " " . .	959·6
6½ " " . .	206·85	15 " " . .	1101·6
7 " " . .	239·88	20 " " . .	1958·4
7½ " " . .	275·40	25 " " . .	3059·9

SCREWS.

Table showing the Number of Threads to an Inch in V-thread Screws.

Diam. in inches, . .	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$
No. of threads, . .	20	18	16	14	12	11	10	9	8	7	7	6

Diam. in inches, . .	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$
No. of threads, . .	6	5	5	$4\frac{1}{2}$	$4\frac{1}{2}$	4	4	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{1}{4}$

Diam. in inches, . .	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6
No. of threads, . .	3	3	$2\frac{7}{8}$	$2\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{1}{2}$

The depth of the threads should be half their pitch. The diameter of a screw, to work in the teeth of a wheel, should be such, that the angle of the threads does not exceed 10°.

RECAPITULATION OF WEIGHTS OF VARIOUS SUBSTANCES.

Names.	Cubic foot in lbs.	Cubic inch in lbs
Cast iron . . .	450·55	·2607
Wrought iron . .	486·65	·2816
Steel	489·8	·2834
Copper	555·	·32118
Lead	708·75	·41015
Brass	537·75	·3112
Tin	456·	·263
White pine . . .	29·56	·0171
Salt water (sea) .	64·3	·03721
Fresh water . .	62·5	·03616
Air	·07529	—
Steam	·03689	—

Cast Iron expands $\frac{1}{162000}$ of its length for one degree of heat; greatest change in the shade, in this climate, $\frac{1}{1170}$ of its length; exposed to the sun's rays, $\frac{1}{1000}$; shrinks in cooling from $\frac{1}{85}$ to $\frac{1}{98}$ of its length; is crushed by a force of 93,000 lbs. upon a square inch; will bear, without permanent alteration, 15,300 lbs. upon a square inch, and an extension of $\frac{1}{1200}$ of its length. Weight of modulus of elasticity for a base of an inch square, 18,400,000 lbs.; height of modulus of elasticity, 5,750,000 feet.

Wrought Iron expands $\frac{1}{143000}$ of its length for one degree of heat; will bear, on a square inch, without permanent alteration, 17,800 lbs., and an extension in length of $\frac{1}{1400}$; cohesive force is diminished $\frac{1}{3000}$ by an increase of one degree of heat. Weight of modulus of elasticity for a base of an inch square, 24,920,000 lbs.; height of modulus of elasticity 7,550,000 feet.

PART SECOND.

INTRODUCTION.

CHOICE OF A PROFESSION: RESPECTABILITY OF MECHANICAL TRADES.

The choice of a pursuit in life, one of the most important practical questions upon which a young person is ever called to decide, is often determined by the most trifling circumstances, and without the slightest aid from judgment or reflection. One youth becomes a soldier because his great grandfather was at the taking of Cape Breton, or his great uncle signalized himself in Braddock's fight; another studies medicine, and hopes to be almost an infallible doctor, because he is the seventh son of a seventh son; while a third chooses the profession of the law for no better reason than that his sponsors at the baptismal font, chose to call him William Wirt, or Daniel Webster, or John Sergeant. Surely this is not that practical wisdom which adapts the fittest means to the noblest ends The choice of a profession

in life is at least worthy of such a consideration as common sense would dictate in any other case, where success in an enterprise depends upon fitness for undertaking it. Men do not expect to gather grapes from thorns, nor figs from thistles; yet they expect their sons and daughters to succeed in pursuits for which they are wholly incapacitated by talents, disposition or education; and what is still more unreasonable, they expect them to be happy in situations which are totally uncongenial to their nature.

One reason why parents and guardians fall so frequently into errors on this point,—errors, too, which they lead those under their charge to embrace,—is the vain imagination that there is a great and essential difference in the respecta bility of those pursuits which are generally admitted to be honest. The respectability of a profession, I suppose it will be admitted, must depend in a great measure on the respectable character of its members, taken collectively, or regarded with reference to the most brilliant examples. If we adopt this standard, it will be found no easy matter to establish a claim to superior respectability in favour of any one

trade or profession, or of any class of trades or professions.

If it should be asserted that the learned professions of law, physic and divinity are more respectable than the pursuits of commerce, mechanics or agriculture, it might be easily shown that taken collectively, the members of these latter professions or trades possess more wealth, ease and independence than those of the learned ones; and moreover, that among them as brilliant examples of mental pre-eminence, patriotism and public spirit may be pointed out as among those of the more learned professions.

In fact, in a country like ours, such a claim of superior respectability on behalf of any profession is preposterous; and yet it is constantly assigned by purse-proud fathers and silly mothers as a reason for determining their children's pursuits in life. There is a very general impression that a merchant, a clergyman, doctor or lawyer stands higher, and should stand higher, in the social scale than a mechanic or farmer. But such is not the fact, as a general principle; or, which results in the same thing, if in a particular instance, a particular merchant, for example, stands higher in social estimation than a particular mechanic, it is not on account

of the respective means by which they earn their livelihood, but because the merchant in this instance has claims by wealth, family influence or education, which the mechanic has not; and by passing into the next street, and taking another example, you will find the tables completely turned, and the mechanic in the enjoyment of a social position to which the merchant cannot aspire. This fact is sufficient to prove that a man of one trade or profession does not take a lower position in society than another of a different profession, simply on account of the different modes by which they subsist, but by reason of other circumstances which are wholly independent of this consideration. Mr. A., who is a merchant, does not, for example, decline an intimate acquaintance and social intercourse with Mr. B., because Mr. B. is a mechanic, but because their favourite topics of conversation, their tastes and pursuits, are different; and this is clearly apparent from another fact, viz.:—that whenever two persons of totally different professions happen to meet frequently upon some common ground of science or the fine arts, in their leisure hours they immediately recognise each other's natural equality and become familiar companions

They collect plants, or minerals, or perform chemical or philosophical experiments together; they unite in the same pursuits during their leisure hours, and become daily more and more assimilated in mind and character, as well as in their favourite recreations, until they are bound together by the strictest bonds of friendship. There is, therefore, no necessary or essential difference in the respectability of different trades and professions; and there is no social estrangement between their members, which may not be overcome by precisely the same means which constitute the cause of intimacy in other circumstances. In our country, therefore, in point of real and essential respectability, all trades and professions are equal; and the social position which a man enjoys, and the degree of respect which he is able to command, depend not upon his trade, but upon his individual character.

If, in every part of the United States, the stupid prejudice which would exclude the mechanic or the farmer from any society to which his intelligence and good manners entitle him, is not thoroughly exploded, the time has certainly arrived when it is no longer to be avowed by well bred people. In fact, the rule which

would exclude a man from any drawing-room in the land, on the simple ground of his being a mechanic, would have excluded from the same drawing-room such men as Nathaniel Bowditch, who was a mariner by trade; Roger Sherman, who was a shoemaker by trade; Benjamin Franklin, late ambassador to the Court of Versailles, who was a printer by trade; and George Washington, a very respectable man of the last century, who was a surveyor by trade.

But the imaginary respectability which a man may happen to enjoy from his position in society, is not by any means the first and most important thing to be considered in the choice of a profession. It should not be the leading motive in determining the choice of the parent; neither should it be the main consideration in the mind of the young person himself. There is another, and a much more important point, which claims and should receive the precedence. Every parent in making choice of a profession for his son, and every son in making the same choice for himself, should seriously and deliberately inquire, what profession affords the best chance for happiness;—happiness, in the noblest and broadest sense—happiness, which consists in contentment, independence,

and real usefulness—happiness, which begins in the conscientious and successful discharge of duty on earth, and reaches forward to the unerring retribution of a future world.

The inquiry which is thus presented is a very extensive one. It admits of whole years of investigation—whole volumes of disquisition to treat it at large, and apply it to any considerable portion of the cases that might arise. In order, therefore, to avoid running into useless generalities, I shall devote the short space which is allotted to me on the present occasion, to a very small part of this great subject, and shall consider that part in a single point of view. I propose, in the outset of the present work, to inquire what opportunities are afforded for usefulness, happiness, and real respectability by the *mechanical trades*—in other words, to inquire how a mechanic may be useful, happy and respectable. In the succeeding chapter I shall consider the first branch of the subject.

CHAPTER I.

THE MECHANIC SHOULD BE MASTER OF HIS TRADE.

In order to become useful, respectable, and happy, it appears to me to be necessary, IN THE FIRST PLACE, that the mechanic should become a thorough master of his trade. Having made a deliberate choice of that pursuit, by which he is to gain his livelihood, it is a matter of the utmost importance that he should devote the energies of his mind to the business unreservedly, until he has mastered all its principles and details. It is by this means only that he can use it with ease and satisfaction as the instrument of success in the world. The incapable, or half taught mechanic, always works at a ruinous disadvantage. He can neither command the highest prices for the products of his art, nor superintend with intelligence and authority the workmen under his care. He is in constant danger of failure in his business, or of abandoning it, through sheer disgust, only to take up some other pursuit for which he is totally unfitted by education. It

is a laudable ambition, therefore, which makes him aspire to be first among his fellows. *Aut Cæsar aut nullus*—a master mechanic, or no mechanic at all—should be his motto.

1. In order to render himself a thorough proficient in his trade, the mechanic should serve out his complete apprenticeship. Justice to himself, as well as to his master, dictates this course. Nor is it less a matter of policy than of moral duty. Even if he should deem himself capable of undertaking the management of business for himself before he has half completed his apprenticeship, it is a much safer and wiser course to remain in a subordinate capacity till he has attained the age of manhood, than to rush upon the heavy duties and fearful responsibilities of active life before his judgment is matured, his understanding ripened, and his nerves hardened for the rough encounter of conflicting interests and unforeseen emergencies.

2. At the same time that I counsel the apprentice to serve out his whole time, I would strenuously urge upon him the importance of devoting any leisure moments that he may have at his command, each day, to the cultivation of his mind. The parent or guardian, in becoming

a party to indentures, should be careful to have a clause inserted by which a certain portion of time shall be secured to the apprentice for mental cultivation; and when this is done the apprentice should regularly consecrate this time to its legitimate purpose. In our large cities facilities for this purpose are judiciously afforded by the beneficent provisions of Mechanics' Institutes, Lyceums and Libraries; but even in situations where such opportunities are not afforded, we know by many illustrious examples that knowledge may be pursued and attained under the most discouraging difficulties. Where that good seed, the love of science, has been once implanted, it will spring up and grow and flourish, though pelted by storms of adversity, and chilled by the coldness of neglect. It is this consideration which encourages the teacher who has the future apprentice under his care, to instil into his opening mind the most liberal and exalted views of the real beauty, as well as utility, of science and literature.

But why, it may be inquired, should the mechanic be inspired with the love of science and literature? I answer, that the mechanic should learn to love these intellectual pursuits for two

reasons:—First, because he is a mechanic; and secondly, because he is a man.

If the physician, the lawyer, the statesman, and the divine avail themselves of the assistance of science and literature in their several professions, the mechanic has still stronger inducements for doing the same thing; for to none of these professions are the results of science so directly applicable, and for none of them are the recreations of literature so appropriate or gratifying. By making himself master of those principles of science which are most intimately connected with his trade, the mechanic, while he is satisfying a liberal curiosity, may possibly be approaching some brilliant discovery, which will speedily conduct him to fortune and fame; and if the lighter reading, generally termed literature, promises no such result, it affords him the most dignified and innocent means of amusement, and preserves the vigour and increases the brightness of his intellect. He should, therefore, learn to appreciate such pursuits, because they are fitting and proper to him as a mechanic.

He may also claim them as his own, upon the broad principle, that wherever there is a human intellect to be cultivated, there is a na-

tural and indefeasible right to the brightest degree of cultivation which it can attain.

I remark, in the next place, that the mechanic, in order to render himself a complete master of his trade, should possess himself of new discoveries in science which are applicable to his purposes, and should actually apply them to the improvement of his trade.

There never was a time since Lord Bacon first placed in the hands of philosophy the right instrument of investigation, when men of science were more actively and successfully engaged in developing the materials and processes directly applicable to the advancement of the mechanic arts, than the present. The forest and the mountain, the mine and the river, the deep bosom of the ocean itself—all are literally ransacked by the ardent devotees of science, in pursuit of new substances which may minister to the sustenance or pleasure of man, or may open to the gaze of liberal curiosity the wonders of creative power. The scientific traveller brings home the products of distant lands to be naturalized in his own country, and thus supply new materials for the useful arts; the mechanical philosopher is constantly adding to the number of known motive

powers; the chemist is discovering new substances, and making new developements and combinations of the powers of those already known; while the press, by means of the art preservative of all arts, is bringing the result of all these labours and inquiries "home to the bosoms and business of men."

At such a time it becomes not the mechanic to be an idle or regardless spectator of all this activity. In the leisure moments which, by an ordinary arrangement of his labours, every man may redeem, he should direct his attention to the progress of discovery in chemistry, mechanical philosophy and natural history, which have a direct bearing on his trade. He should attach himself to that mechanics' institute or lyceum which affords him the best means of improvement by its lectures, experiments, and library. He should cultivate the acquaintance of those scientific men who have the good sense to appreciate the society of intelligent practical mechanics, and he should apply the results of his inquiries, so far as it may be judiciously done, to the perfecting of his own manufactures. In recommending such a course to the young mechanic, I know that I am not urging upon him vain speculations in visionary

schemes. That such a course is precisely the one best calculated to improve and develope the mechanical arts, is clearly apparent whenever an exhibition of the products of American industry is opened by any one of the societies constituted and supported by mechanics for this very purpose. A single exhibition of the Franklin Institute establishes with more certainty than a whole volume of arguments, the soundness of that policy which leads the mechanic to devote his winter evenings to scientific pursuits, and to apply the result of his study to the improvement of his own trade.

CHAPTER II.

THE MECHANIC SHOULD REMAIN ATTACHED TO HIS TRADE.

This is not all that is requisite for the usefulness, happiness, and respectability of the mechanic. In order to secure these objects fully, I maintain, in the second place, that it is necessary for him to remain attached to his trade. Recent events in this country have, I think, sufficiently demonstrated the pernicious tendency of that ambitious restlessness which has lately pervaded all classes of people, and made almost every man regard his business whatever it happened to be, as merely the stepping stone to something apparently higher. Apparently, I say, for we have seen in many instances that mechanics, who were slowly and surely acquiring the means of independence and comfort, have dashed into wild speculations, in hopes to rise to some imaginary height of wealth and importance; but when the glittering bauble was almost within their reach, have found it suddenly elude their grasp and leave

them to regret the loss of all which they had been toiling for years to acquire.

Contentment, like every other Christian duty, has a great many excellent uses. It is good for the mind, for the body, and for the estate of every man. It tranquillizes the spirit, it preserves the health, and it promotes that steady economy which leads to competency; often to affluence. The man who is satisfied with the position which Providence has assigned him, and endeavours to make himself useful in that position, presents a vastly more respectable figure than one who is constantly struggling to place himself in a different position. The fruits of this struggle are harassing cares, jealous heart-burnings, hazardous enterprises, and often debt and ruin. There is an old and homely saying, applicable to every one who has been brought up to a regular trade or profession—a saying full of practical wisdom, which many have hitherto disregarded, but which will be better observed in years to come—"Keep your shop, and your shop will keep you." This saying, as I have already intimated, is a wholesome one for any man who labours for his subsistence, whether it be with his head or his

hands; but for the mechanic it is the ark of safety.

In some foreign countries it is the custom for mechanics to form associations, of which one of the leading objects is to retain all the members of each trade in the trade to which he belongs. For this purpose they not only aid all their brethren who are in distress, but they use every exertion to retain within their circle all the talent and all the wealth which has originated among them. Their public institutions, libraries and lecture rooms, their scientific collections, their pictures and models, afford the means of gratifying the most refined taste; and these and the tone which is imparted to their circle of society by this noble *esprit de corps*, make it wholly unnecessary for the most ambitious person to leave the trade in pursuit of any of these objects. Any one may see that under such circumstances it is a nobler object of ambition to be highly respected in the trade, than can be attained by means of any position out of it. The same principle holds good under all circumstances. If a man has surrounded himself with all the elegancies and luxuries which affluence can purchase by diligence and industry in his trade, he should

never abandon it under the impression that he will thus elevate himself in the estimation of his fellow citizens, by putting on a finer coat, and appearing in a different character. Such a course calls down a torrent of invidious remarks, not from his brethren of the trade, who are content, for the most part, to regret the desertion in silence, but the rest of that little world by whose Argus eyes the movements of each individual in society is watched. On the other hand, the mechanic who remains attached to his trade, when it is no longer absolutely necessary for his support, is universally respected for this mark of steadiness, constancy and good sense. In connection with this part of my subject, I am strongly reminded of an old acquaintance of my own, in the old commonwealth of Massachusetts, who evidently takes an honest pride in his adherence to that trade which has long since given him the most ample means of luxury and ease. This gentleman is referred to by Governor Everett, in one of his recent public addresses, in the following terms:

"I scarce know if I may venture to adduce an instance, nearer home, of the most praiseworthy and successful cultivation of useful knowledge, on the part of an individual with-

out education, busily employed in mechanical industry. I have the pleasure to be acquainted, in one of the neighbouring towns, with a person, who was brought up to the trade of a leather-dresser, and has all his life worked, and still works, at this business. He has devoted his leisure hours, and a portion of his honourable earnings, to the cultivation of useful and elegant learning. Under the same roof, which covers his store and workshop, he has the most excellent library of English books, for its size, with which I am acquainted. The books have been selected with a good judgment, which would do credit to the most accomplished scholar, and have been imported from England by himself. What is more important than *having* the books, their proprietor is well acquainted with their *contents.* Among them are several volumes of the most costly and magnificent engravings. Connected with his library, is an exceedingly interesting series of paintings, in water-colours, which a fortunate accident placed in his possession, and several valuable pictures, purchased by himself. The whole form a treasure of taste and knowledge, not surpassed, if equalled, by any thing of its kind in the country."

Governor Everett might have added that the leading traits in Mr. Dowse's character are sound sense and good taste; and no more decisive proof of these characteristics could be given than his steady adherence to his original business. In the same address from which the above paragraph is quoted, the eloquent orator urges upon his hearers that every working man should cultivate his mind to the utmost of his ability; and he quotes examples of many who have thus raised themselves to conspicuous offices and honours. I would urge upon all working men the same duty of mental cultivation, not as affording the opportunity of abandoning their trade; but as giving them the means of dignifying and embellishing it. Lorenzo de Medicis by commerce raised his family to princely rank—they were the merchant kings of their age. The American mechanic has no occasion to seek any advancement of this sort, for every voter in our country is something greater than a king; by virtue of the elective franchise he is a maker of kings. When I speak of adhering to one's trade, I would by no means be understood to lay down a rule without exceptions. Emergencies may occur which shall render it a paramount duty to enter

upon a new and difficult profession. The mechanic, like any other citizen, may be suddenly called upon to shoulder his musket and defend his country from invasion, as happened in the case of General Greene; or he may be required to aid the same great cause by his wisdom in council, as in the case of Sherman and Franklin. When a country is to be saved by valour or wisdom, it becomes a matter of absolute necessity that the working men should contribute a large contingent towards the grand army of defence as well as the council of the nation. For a time, at least, a new course of life must then be embraced. But the greatest, and most celebrated among those who have been detached from their trade in this or in any other way, have always shown an honest pride in their original calling. Girard wrote himself mariner in his will; and Franklin called himself printer in his epitaph.

CHAPTER III.

THE MECHANIC SHOULD HONOUR HIS TRADE.

I HAVE already insisted that the mechanic in order to be useful, happy and respectable, should become a thorough master of his trade, and should remain attached to it. I would in the next place urge upon him the duty and policy which dictate that he should *honour his trade*. There are two ways in which this may be done: first, by seeking distinction in it; and secondly, by adorning it with intellectual recreations.

The love of distinction is common to nearly all men; and the most remarkable and conspicuous diversities of character are produced by the different modes in which this favourite object is pursued. One man seeks it by brilliant deeds in the public service, another by munificent institutions. Here we see distinction courted by eloquence, and there by learning Some hope to become distinguished by their literary efforts, or their scientific discoveries, while others, with a less laudable, but not less

earnest ambition, seek to attract public attention by mere eccentricity of character or extravagance in conduct, dress or equipage. Doubtless this passion, so generally prevalent among men, has been implanted in the human breast for a wise and useful purpose; and it is therefore right to allow it a field for action, provided that field be a safe and honourable one. If this postulate be granted, I would ask what could afford a fairer and nobler field for any man's ambition, than the pursuit of distinction by extraordinary excellence in his trade or profession. Each of the mechanical trades affords ample room for the exercise of ingenuity in the improvement of its processes, and the consequent improvement of its products; and the free institutions and abundant resources of our country, and the ease with which the workman may support himself, has already enabled American industry and invention in many instances to claim the admiration of the world. It must be a proud reflection to the American mechanic, that one of his class has exacted the most unequivocal homage to the genius of our country from the proud Sultan of the East, by his wonderful skill as a naval constructor; and every Philadelphian may justly entertain a feeling of

exultation when he remembers that a mechanic of one of our cities is at this moment furnishing locomotive engines, acknowledged to be superior to all others, for the use of British and Austrian rail road companies. Such distinction as this we must acknowledge to be fairly and honourably won. It is true that all may not hope to rise so high in the world's estimation as to attract applause from foreign countries. But every one may reap the reward of diligence, ingenuity and devotion to his business, in the applause of that valued circle, which is, in a certain sense, all the world to him—the circle of his associates and friends.

Again, the mechanic may honour his trade by adorning it with intellectual recreations. It is not desirable, in fact it is not possible for a man to devote every moment of his time to the business by which he lives. Such intense application is injurious both to the body and the mind. It destroys health, racks the brain, and ruins the temper. The repose of the domestic circle, the quiet hour for reading or music, or relaxation of some other kind, seems absolutely necessary for the preservation of that greatest of earthly blessings—a sound mind in a healthy body. The business of the mechanic is pre-

cisely that which renders it most expedient for him to give his recreations an intellectual cast; and it is owing to the circumstance that the alternation of mental and bodily labour is best suited to the human constitution, that some of the most beautiful and brilliant productions of the human intellect have proceeded from those persons who were compelled, for many hours of each day, to labour at a business which was purely mechanical. Cast your eye over the whole field of English literature, and see who it is that has brought the art of essay writing to its greatest perfection. Of course you instantly answer, Charles Lamb. He is universally acknowledged to be in this department inimitable, unrivalled, unapproachable. The best critics say that we can never hope to see such essays produced by any other writer. Yet these beautiful productions were the work of leisure evenings. The composition of them served as a relaxation, after severe labour through the day at the India House in copying commercial papers, which to him must have been a perfectly mechanical operation. Nevertheless, he had the good sense to adhere to this, his trade, long after he was one of the most famous writers in England, and in fact until his

age and services entitled him to a retiring pen sion. I will not weary your patience by citing other examples, although there are thousands at hand, in proof of my position that intellectual recreations are particularly appropriate for the mechanic, and that they form the proper and legitimate ornament of his trade.

Coleridge, an author by profession, tells us in plain terms that it is necessary, in order to be successful in works of imagination, to have some profession or trade which is to a certain extent mechanical, and he affectionately exhorts all young people to avoid his own profession if they would be useful and happy. I cite his observations, which are as remarkable as they are just.

"An interest in the welfare of those who, at the present time, may be in circumstances not dissimilar to my own at my first entrance into life, has been the constant accompaniment, and, (as it were,) the under-song of all my feelings. Whitehead, exerting the prerogative of his laureateship, addressed to youthful poets a poetic charge, which is perhaps the best, and certainly the most interesting of his works. With no other privilege than that of sympathy and sincere good wishes, I would address an affectionate

exhortation to the youthful literati, grounded on my own experience. It will be but short; for the beginning, middle, and end, converge to one charge: Never pursue literature as a trade. With the exception of one extraordinary man, I have never known an individual, least of all, an individual of genius, healthy or happy without a profession, i. e. some regular employment which does not depend on the will of the moment, and which can be carried on so far mechanically, that an average quantum only of health, spirits, and intellectual exertion, are requisite to its faithful discharge. Three hours of leisure, unannoyed by any alien anxiety, and looked forward to with a delight as a change and recreation, will suffice to realize in literature, a larger product of what is truly genial, than weeks of compulsion. Money and immediate reputation, form only an arbitrary and accidental end of literary labour. The hope of increasing them, by any given exertion, will often prove a stimulant to industry; but the necessity of acquiring them will, in all works of genius, convert the stimulant into a narcotic. Motives by excess reverse their very nature, and, instead of exciting, stun and stupify the mind. For it is one contradistinction

of genius from talent, that its predominant end is always compromised in the means; and this is one of the many points which establish an analogy between genius and virtue. Now, though talents may exist without genius, yet, as genius cannot exist, certainly not manifest itself, without talents, I would advise every scholar who feels the genial power working within him, so far to make a division between the two, that he should devote his talents to the acquirement of competence in some known trade or profession, and his genius to objects of his tranquil and unbiassed choice; while the consciousness of being actuated in both alike by the sincere desire to perform his duty, will alike ennoble both. My dear young friend, (I would say,) 'suppose yourself established in any honourable occupation. From the manufactory, or counting-house, from the law court, or from having visited your last patient, you return at evening—

> Dear tranquil time, when the sweet sense of home
> Is sweetest—

to your family, prepared for its social enjoyments, with the very countenances of your wife and children brightened, and their voice of welcome made doubly welcome by the know-

ledge that, as far as they are concerned, you have satisfied the demands of the day, by the labour of the day. Then when you retire into your study, in the books on your shelves you revisit so many venerable friends with whom you can converse. Your own spirit, scarcely less free from personal anxieties than the great minds that, in those books, are still living for you! Even your writing desk with its blank paper, and all its other implements, will appear as a chain of flowers, capable of linking your feelings, as well as thoughts, to events and characters past or to come; not a chain of iron, which binds you down to think of the future, and the remote, by recalling the claims and feelings of the preremptory present. But why should I say *retire?* The habits of active life and daily intercourse with the stir of the world, will tend to give you such self-command, that the presence of your family will be no interruption. Nay, the social silence or undisturbing voices of a wife or sister, will be like a restorative atmosphere, or soft music, which moulds a dream without becoming its object. If facts are required, to prove the possibility of combining weighty performances in literature with full and independent employment, the

works of Cicero and Xenophon among the ancients, of Sir Thomas More, Bacon, Baxter, or, to refer, at once, to later and contemporary instances, Darwin and Roscoe, are at once decisive of the question.

"Whatever be the profession or trade chosen, the advantages are many and important, compared with the state of a mere literary man, who, in any degree, depends on the sale of his works for the necessaries and comforts of life. In the former, a man lives in sympathy with the world in which he lives. At least, he acquires a better and quicker tact for the knowledge of that with which men in general can sympathize. He learns to manage his genius more prudently and efficaciously. His powers and acquirements gain him likewise more real admiration, for they surpass the legitimate expectation of others. He is something besides an author and is not therefore considered merely as an author. The hearts of men are open to him, as to one of their own class; and whether he exerts himself or not in the conversational circles of his acquaintance, his silence is not attributed to pride, nor his communicativeness to vanity. To these advantages I will venture to add a superior chance of hap-

piness in domestic life, were it only that it is as natural for the man to be out of the circle of his household during the day, as it is meritorious for the woman to remain for the most part within it. But this subject involves points of consideration so numerous and so delicate, and would not only permit, but require such ample documents from the biography of literary men, that I now merely allude to it *in transitu.* When the same circumstance has occurred at very different times to very different persons, all of whom have some one thing in common, there is reason to suppose that such circumstance is not merely attributable to the persons concerned, but is in some measure occasioned by the one point in common to them all. Instead of the vehement and almost slanderous dehortation from marriage, which the 'Misogyne Boccaccio' (*Vita e Costumi* di Dante, p. 12. 16) addresses to literary men, I would substitute the simple advice: be not merely a man of letters! Let literature be an honourable augmentation to your arms, but not constitute the coat, or fill the escutcheon!

"It would be a sort of irreligion, and scarcely less than a libel on human nature, to believe that there is any established and reputable pro-

fession or employment, in which a man may not continue to act with honesty and honour; and, doubtless, there is likewise none which may not at times present temptations to the contrary. But wofully will that man find himself mistaken, who imagines that the profession of literature, or (to speak more plainly) the *trade* of authorship, besets its members with fewer or with less insidious temptations, than the church, the law, or the different branches of commerce.' "

Charles Lamb himself subscribes to this opinion of Coleridge, and urges it upon one of his friends with great force; and Herder is quoted by Coleridge in support of his own opinion, as follows:

Translation.—" With the greatest possible solicitude avoid authorship. Too early, or immoderately employed, it makes the head waste and the heart empty, even were there no other worse consequences. A person who reads only to print, in all probability reads amiss; and he who sends away through the pen and the press, every thought, the moment it occurs to him, will in a short time have sent all away, and will become a mere journeyman of the printing office, a compositor."

So much for the opinion of great authors on the character of their trade.

In all these observations you find it distinctly admitted that the fancy, the imagination, the creative powers of the mind are not to be taxed for the purposes of mere support. They say it is better to work for a living at some business which is mechanical, by way of a regular trade or profession, and to give the genius free play in the hours of recreation. That such a distribution of one's time may produce the happiest effect is abundantly apparent from the experience of all ages. Without adverting to the busy life led by Cicero and Quinctilian, whom I esteem among the best authors of ancient times, we may come down at once to the moderns. Bacon, the prince of philosophers, was a lawyer laboriously active in his profession during the greater part of his life; Shakspeare, the most admirable of all writers, was a player and manager, and was obliged to work hard at the mechanical part of these laborious employments; Raleigh was a soldier and statesman, one of the most active of his age; Clarendon was a busy statesman and lawyer; Addison was secretary of state while he was writing the Spectator; Walter Scott was a writer for

the signet, and sheriff of the county; and it is a curious fact that this writer, the most prolific as well as the best of our century, passed his days in bodily labour, riding about the county or working at his profession. It was remarked that nobody could conjecture when it was that he found time to write his voluminous works.

If we come to our own country, the examples are more numerous. All our best authors are working men. Prescott is a lawyer; Bancroft, a teacher for some years, and afterwards collector of the port of Boston; Charles Sprague is a bank clerk; Halleck collects Mr. Astor's rents; Dana is a lawyer; Longfellow, a teacher. In fact, with us, authorship is seldom a profession. Most of our literature has been produced in the leisure hours rescued from laborious occupations.

Our scientific and useful inventions too have generally resulted from the very course which I am desirous to recommend to the mechanic, viz.: that of honouring his trade by adorning it with intellectual recreations. Fulton was a portrait painter, who amused himself in his idle hours with experiments on steam power; Whitney, the inventor of the cotton gin, was a machinist, whose judicious employment of his

leisure moments led him to an invention which has trebled the value of cotton lands at the South; Whittemore, of West Cambridge, who invented the machinery for the manufacture of cards, was, if I recollect right, a cabinet maker. The case of Franklin is familiar to all.

All these examples tend to establish the same truth,—that a mechanical business, a life of activity and labour, is far from being unfavourable to the highest operations of the intellect; and that relaxation from active labours is most appropriately found in mental recreations.

CHAPTER IV.

THE MECHANIC SHOULD DEVOTE HIS LEISURE TO THE GENERAL INTERESTS OF HIS TRADE.

One more duty I would urge upon the mechanic, in order to the finishing of his character of a useful, happy and respectable man. Having attained wealth at the time of life when it is desirable to cease from active labour, I would have him devote himself to the general interests of his trade.

There are many ways in which the wealthy mechanic may promote the general interests of his trade, when he has retired from all participation in its labours or profits.

He may give a tone to its society by exercising a refined and judicious hospitality. He may make his house the resort of kindred spirits, who will unite with him in their endeavours to retain men of talent and influence in the trade. He may assist young men who are entering upon business for themselves with money, credit and good advice. He may save many a brother from ruin by interposing a friendly

voice, and a helping hand at the critical moment when they are most needed. He may become in his old age the Mecænas, as well as the Nestor of his fraternity, by patronizing the intellectual efforts of their leisure hours.

Such was the course of Franklin; and his munificent aid ceased not with his life. In his will a permanent fund was established for aiding the young mechanics of his native place by loans of money. The example of his life, however, has been of more value than a legacy of millions. He was a mechanic who fulfilled the several conditions which we have been considering as necessary to happiness, usefulness and respectability. He made himself a thorough master of his trade; he adhered to it till the imperative call of his suffering country compelled him to relinquish it; and he honoured his trade by seeking distinction in it, and by adorning it with intellectual recreations. Long may his example be imitated by his countrymen—long may his race live and flourish in the land. Such mechanics are the bulwark of our free institutions. While we have men of the Franklin stamp among us, we shall never want a supply of heroes and statesmen to perform great and brilliant actions, or poets, historians and orators to celebrate them.

CHAPTER V.

MISDIRECTION OF INDUSTRY—PREJUDICES AGAINST THE MECHANICAL TRADES.

Among the many causes which have led to the present depressed state of affairs in our country, there is one which appears to me an efficient one, although it has been in a great measure overlooked. This is the misdirection of industry—of productive labour. All observers readily perceive that *capital* has been thrown away; few take notice of the fact that hands and heads have been employed on works that are now known to be utterly useless. Railroads, for example, have been constructed, which can never, by any possibility, be required for the public accommodation to such an extent as to pay the expense of keeping them in repair and employing lines of cars upon them. Mines have been opened and wrought in situations where no veins of metal existed, although the imaginations of the stockholders, aided by the fine stories of some cunning Dousterswivel, had made each of the re-

gions a perfect El Dorado. Even agricultural labour has been misapplied; for trees have been planted and nursed with the greatest care, under the impression that their leaves were to be converted into silks which should rival the fabrics of Lyons and Benares; and yet these very trees have subsequently been cut down as cumberers of the ground.

The productive industry of this country might just as well have been employed in the construction of pyramids, like those of the ancient Egyptians, as on works of this nature. It is literally labour, time, and talents thrown away.

But these are not the only ways in which labour, time and talent have been misdirected. Thousands of our young men have entered the learned professions when they were already crowded, and are consequently wasting their lives in vain hopes; and other thousands have devoted themselves to the pursuits of commerce without capital, prudence, or intelligence sufficient to avoid the dangers of commercial enterprize; and these men are now either bankrupts, or involved in a series of embarrassments which may last through their whole lives. An error in the choice of one's profession is one which is followed by painful consequences, as

many have found to their cost. In this country we are apt to be too ambitious and restless. The freedom of our institutions, instead of impressing upon us the wholesome lesson that all men are naturally equal in dignity, and that consequently every trade and profession may be ennobled by the personal merit of its members, leads men to aspire to certain professions which they esteem genteel; and to high offices which the constitution has made attainable by citizens of all classes.

This is wrong. An American should respect himself. A citizen of this republic should deem himself a peer of the world—one of nature's noblemen. He should consider that the circumstance of his being an American citizen is sufficient to adorn with all proper dignity any trade or profession which he may adopt. Having settled this point with himself, he is left at perfect liberty to look around with an unprejudiced mind, upon the different modes of obtaining subsistence and making himself useful to the community; and he can make his choice upon the same principles that should govern him in deciding any practical question. In taking a survey of some large community with reference to the success which has attend-

ed the exertions of other men, in order to aid his judgment in the choice of a profession, the youth or his adviser may peradventure, arrive at some results which he did not anticipate.

Suppose, for example, that he should examine the comparative success of those men whom we know to have devoted themselves to *mechanical* trades, and those who have become *merchants.* Would it not be apparent that where one mechanic has failed and caused extensive losses to his friends and the community, ten merchants have done the same thing? On the other hand, would it not appear that where one merchant had acquired a competent fortune and retired from business in the decline of life, several mechanics have done the same thing? If we were to run over the list of persons taxed for real estate, should we not find more mechanics than merchants living in their own houses, and deriving a handsome income from their rents?

If it be said that this not a fair test of comparative success, let another be resorted to. Take the whole number of persons employed in mechanical trades, and the whole number of persons employed in commerce, say for the last twenty years; then calculate what per centage

of each class has failed, what per centage has gained a decent subsistence without failing, and what per centage has arrived at what is called independence. The result of such an inquiry would satisfy the inquirer that it is a safer course to become a mechanic than to be a merchant.

The prejudice against the mechanical trades is a relic of feudalism unworthy of our free country. Considered with reference to those old feudal prejudices, all the pursuits by which bread is earned in our country are equally base. Considered in the light of republican philosophy, they are all equally honourable. The baron of the middle ages, who could not read or write, looked down upon the merchant, the mechanic, and the lawyer with equal contempt; and the baron of modern days, who cannot even wield a lance, considers himself superior to the greatest, wisest, and best of those who were born commoners. These old feudal prejudices are ridiculous. But when *we* call one profession *respectable*, and another *less respectable*, do we not adopt them? When we talk of degrading ourselves by making tradesmen of our sons, do we not give sanction to the stupid and exploded notions of the

dark ages? When we admit that any citizen may *lose caste* by associating with any other honest and honourable man, do we not submit to a barbarism worse than Gothic—the barbarism of Hindostan and China?

Such notions should be laid aside with other useless lumber, as unfit for an age and a country where common sense gives law to society, and where real merit stamps the seal of respectability. It is but fighting shadows to offer arguments in opposition to such views. I gladly turn therefore from this to the more agreeable task of continuing the subject of my last lecture—the mechanic.

CHAPTER VI.

INTELLECTUAL CULTIVATION OF THE MECHANIC—ITS IMPORTANCE.

I PROPOSE now to offer a few remarks on the intellectual cultivation of the mechanic, its importance, its means, and its rewards.

That intellectual cultivation, as a means of moral and social elevation, is as important to the mechanic as it is to any other citizen, is a truth so obvious as not to require argument or illustration for its support. But this is not all He has stronger reasons for study than most other men. His very livelihood may depend in a great measure on a degree of skill in his art which cannot be acquired without a knowledge of the scientific principles and natural laws on which the arts are founded.

The whole system of mechanics' institutes, lyceums, lectures, and collections of specimens and machines, is nothing more nor less than an open confession made by the mechanics themselves, that intellectual cultivation has become absolutely necessary, in order that they may

keep pace with the spirit of the age—an acknowledgment that the time has come when science and art shall be firmly united, and the head and the hands shall work together.

Competition imposes upon the mechanic of the present day the necessity of study. Unless he keeps pace with the intelligence of the times, he will speedily find himself working at a ruinous disadvantage. While the workman who is content to remain stationary in scientific intelligence, neglects the opportunities of information afforded by the institute, the reading room, and a constant social intercourse with the most intelligent of his trade; his neighbour, availing himself of these advantages, may possess himself of new processes, new materials, or new facts, which will enable him to reduce his prices, and in a great measure to carry off the custom of the place.

It was not always thus. Monopoly and prescription formerly exerted an influence as injurious to the arts as that which is now exerted by competition is beneficial.

Indeed, as has been ably shown by a learned authority,* much mischief has been occasioned

* Governor Everett. Oration, p. 232.

in past times by the ignorance of artizans. He says :—

"The history of the progress of the human mind shows us, that for want of a diffusion of scientific knowledge among practical men, great evils have resulted, both to science and practice. Before the invention of the art of printing, the means of acquiring and circulating knowledge were few and ineffectual. The philosopher was, in consequence, exclusively a man of study, who, by living in a monastic seclusion, and by delving into the few books which time had spared,—particularly the works of Aristotle and his commentators,—succeeded in mastering the learning of the day; learning, mostly of an abstract and metaphysical nature. Thus, living in a world not of practice, but speculation, never bringing his theories to the test of observation, his studies assumed a visionary character. Hence the projects for the transmutation of metals; a notion not originating in any observation of the qualities of the different kinds of metals, but in reasoning, *a priori*, on their supposed identity of substance. So deep rooted was this delusion, that a great part of the natural science of the middle ages consisted in projects to convert the

baser metals into gold. It is plain, that such a project would no more have been countenanced by intelligent, well-informed persons, practically conversant with the nature of the metals, than a project to transmute pine into oak, or fish into flesh.

"In like manner, by giving science wholly up to the philosophers, and making the practical arts of life merely a matter of traditionary repetition from one generation to another of uninformed artists, much evil of an opposite kind was occasioned. Accident, of course, could be the only source of improvement; and for want of acquaintance with the leading principles of mechanical philosophy, the chances were indefinitely multiplied against these accidental improvements. For want of the diffusion of information among practical men, the principles prevailing in an art in one place were unknown in other places; and processes existing at one period were liable to be forgotten in the lapse of time. Secrets and mysteries, easily kept in such a state of things, and cherished by their possessor as a source of monopoly, were so common, that *mystery* is still occasionally used as synonymous with *trade*. This also contributed to the loss of arts once brought to per-

fection, such as that of staining glass, as practised in the middle ages. Complicated machinery was out of the question; for it requires, for its invention and improvement, the union of scientific knowledge and practical skill. The mariner was left to creep along the coast, while the astronomer was casting nativities; and the miner was reduced to the most laborious and purely mechanical processes, to extract the precious metals from the ores that really contained them, while the chemist, who ought to have taught him the method of amalgamation, could find no use for mercury, but as a menstruum, by which baser metals could be turned into gold.

"At the present day, this state of things is certainly changed. A variety of popular treatises and works of reference have made the great principles of natural science generally accessible. It certainly is in the power of almost every one, by pains and time properly bestowed, to acquire a decent knowledge of every branch of practical philosophy. But still, it would appear, that, even now, this part of education is not on the right footing. Generally speaking, even now, all actual instruction in the principles of natural science is confined

to the colleges; and the colleges are, for the most part, frequented only by those intended for professional life. The elementary knowledge of science which is communicated at the colleges, is indeed useful in any and every calling; but it does not seem right that none but those intended for the pulpit, the bar, or the profession of medicine, should receive instruction in those principles which regulate the operation of the mechanical powers, and lie at the foundation of complicated machinery; which relate to the navigation of the seas, the smelting and refining of metals, the composition and improvement of soils, the reduction to a uniform whiteness of the vegetable fibre, the mixture and application of colours, the motion and pressure of fluids in large masses, the nature of light and heat, the laws of magnetism, electricity, and galvanism. It would seem that this kind of knowledge was more immediately requisite for those who are to construct or make use of labour-saving machinery, who are to traverse the ocean, to lay out and direct the excavation of canals, to build steam engines and hydraulic presses, to work mines, and to conduct large agricultural and manufacturing establishments. Hitherto, with some

partial exceptions, little has been done, systematically, to afford to those engaged in those pursuits, that knowledge which, however convenient to others, would seem essential to them. There has been scarce any thing, which could be called education for practical life; and those persons who, in the pursuit of any of the useful arts, have signalized themselves by the employment of scientific principles for the invention of new processes, or the improvement of the old, have been self-educated men."

It is argued, in opposition to this view of the matter, that the greatest discoveries and inventions have been produced by self-taught men, or by accidental circumstances, and that education is therefore unnecessary for the mechanic. The *fact* is indisputable; but the argument founded on it against the intellectual cultivation of working men, is not sound. Another fact will sufficiently refute it. Before education became generally diffused among mechanics, useful discoveries and inventions were much rarer than they are at present. When the great mass of mechanics could neither read nor write, the progress of invention was exceedingly slow. Now it is astonishingly rapid. In the middle ages great discoveries in the arts were

made at the rate of about one in a hundred years. Now they are made almost every year. Within the range of our own recollection two great motive powers, unknown before, have been rendered available in the arts of life, and scarcely a month passes without the announcement of some new contrivance for economizing the labour of man. This fact not only answers the argument already cited, but acts with tremendous power on the opposite side: thus,

The increase of education among mechanics increases the number of discoveries and improvements in the arts, by which human labour is abridged. This increase of power is an increase of happiness. It elevates the mechanic in the scale of social being, and adds to the comfort—the essential happiness of society. By means of the recent improvements in the arts effected by ingenious and educated mechanics, the amount of severe bodily labour previously imposed on that class of men is greatly diminished; and this is no small gain.

"We read," says a shrewd writer, "we read in many authors great encomiums on a life of *labour*, and of the superior blessings of peasants and hard-working men, whose temperate and abstemious lives not only make them enjoy an

uninterrupted state of health, but throw a crimson on their cheeks, and give a vigour to their bodies, the sons of wealth and affluence, they tell us, may in vain sigh for. This sounds well; but I own I am doubtful of the fact.

"If I compare the working part of mankind, who fare hard, with those who eat and drink of the 'good things of the earth,' I think I can discern better complexions, choicer animal spirits, and stronger bodies in the latter than in the former. Incessant labour and coarse and scanty food, have certainly a tendency to weaken the bodies of mankind, and wear them out before their time; and this we see is the case. What becomes then of the fine-spun theories of visionary authors who so greatly extol a laborious life? Why, they are destroyed, like other cobweb systems, that will not bear handling."

Education multiplies the inventions which lighten bodily labour. Education among mechanics is, therefore, a great blessing; and it should be a settled policy with this large and influential class of citizens, to encourage in every possible way the intellectual cultivation of all who compose their body.

The kind of education which is suitable for

a mechanic is that which is best accommodated to his circumstances. It should be liberal,—not minute. To learn the practical application of every science to every art, is not in the power of any single individual; but the mechanic, as well as the professed scholar, may learn the general laws and principles of science; and subsequently carry out to any degree which may seem expedient for him, those details which are particularly applicable to his own trade. His general acquaintance with the physical laws will enlarge his sphere of usefulness, and increase his chances of success in any particular art.

There are many good reasons why the American mechanics, more than those of any other nation, should cultivate science. One reason of this is the exalted station in society which he enjoys here, compared with that assigned to the same class of men in other countries.

In this connexion, I will again quote the authority of Governor Everett.

And first, he says, it is beyond all question, that what are called the mechanical trades of this country are on a much more liberal footing than they are in Europe. This circumstance not only ought to encourage those who

pursue them, to take an honest pride in improvement, but it makes it their incumbent duty to do so. In almost every country of Europe, various restraints are imposed on the mechanics, which almost amount to slavery. A good deal of censure has been lately thrown on the journeymen printers of Paris, for entering into combinations not to work for their employers, and for breaking up the power presses, which were used by the great employing printers. I certainly shall not undertake to justify any acts of illegal violence, and the destruction of property. But when you consider that no man can be a master printer in France without a license, and that only eighty licenses were granted in Paris, it is by no means wonderful that the journeymen, forbidden by law to set up for themselves, and prevented by the power presses from getting work from others, should be disposed, after having carried through one revolution for the government, to undertake another for themselves. Of what consequence is it to a man, forbidden by the law to work for his living, whether Charles X. or Louis Philip is king?

In England, it is exceedingly difficult for a mechanic to obtain a settlement in any town

except that in which he was born, or where he served his apprenticeship. The object of imposing these restrictions is, of course, to enforce on each parish the maintenance of its native poor; and the resort of mechanics from place to place is permitted only on conditions with which many of them are unable to comply. The consequence is, they are obliged to stay where they were born; where, perhaps, there are already more hands than can find work; and, from the decline of the place, even the established artisans want employment. Chained to such a spot, where chance and necessity have bound him, the young man feels himself but half free. He is thwarted in his choice of a pursuit for life, and obliged to take up with an employment against his preference, because there is no opening in any other. He is depressed in his own estimation, because he finds himself unprotected in society. The least evil likely to befall him is, that he drags along a discouraged and unproductive existence. He more naturally falls into dissipation and vice, or enlists in the army or navy; while the place of his nativity is gradually becoming a decayed, and finally a rotten borough, and, as such, enables some rich nobleman to

send two members to parliament, to make laws against combinations of workmen.

In other countries singular institutions exist, imposing oppressive burdens on the mechanical classes. I refer now more particularly to the corporations, guilds, or crafts, as they are called, that is, to the companies formed by the members of a particular trade. These exist, with great privileges, in every part of Europe; in Germany, there are some features in the institution, as it seems to me, peculiarly oppressive. The different crafts in that country are incorporations recognized by law, governed by usages of great antiquity, with funds to defray the corporate expenses, and in each considerable town, a house of entertainment is selected, as the house of call (or harbour, as it is styled,) of each particular craft. No one is allowed to set up as a master workman, in any trade, unless he is admitted as a freeman, or member of the craft; and such is the stationary condition of most parts of Germany, that I understand that no person is admitted as a master workman in any trade, except to supply the place of some one deceased or retired from business. When such a vacancy occurs, all those desirous of being permitted to fill it, present a piece of

work, which is called their master-piece, being offered to obtain the place of a master workman. Nominally, the best workman gets the place; but you will easily conceive, that, in reality, some kind of favouritism must generally decide it. Thus is every man obliged to submit to all the chances of a popular election, whether he shall be allowed to work for his bread; and that too, in a country where the people are not permitted to have any agency in choosing their rulers. But the restraints on journeymen, in that country, are still more oppressive. As soon as the years of apprenticeship have expired the young mechanic is obliged, in the phrase of the country, to *wander* for three years. For this purpose he is furnished by the master of the craft in which he has served his apprenticeship, with a duly authenticated wandering book, with which he goes forth to seek employment. In whatever city he arrives, on presenting himself, with this credential, at the house of call, or harbour, of the craft in which he has served his time, he is allowed, gratis, a day's food and a night's lodging. If he wishes to get employment in that place, he is assisted in procuring it. If he does not

wish to, or fails in the attempt, he must pursue his wandering; and this lasts for three years, before he can be any where admitted as a master. I have heard it argued, that this system had the advantage of circulating knowledge from place to place, and imparting to the young artisan the fruits of travel and intercourse with the world. But however beneficial travelling may be, when undertaken by those who have the capacity to profit by it, I cannot but think that to compel every young man, who has just served out his time, to leave his home, in the manner I have described, must bring his habits and morals into peril, and be regarded rather as a hardship than as an advantage. There is no sanctuary of virtue like home.

You will see, from these few hints, the nature of some of the restraints and oppressions to which the mechanical industry of Europe is subjected. Wherever governments and corporations thus interfere with private industry, the spring of personal enterprise is unbent. Men are depressed with a consciousness of living under control. They cease to feel a responsibility for themselves, and, encountering obstacles whenever they step from the beaten path, they give up improvement as hopeless. I need

not remark on the total difference of things in America. We are apt to think, that the only thing in which we have improved on other countries, is our political constitution, whereby we choose our rulers, instead of recognizing their hereditary rights. But a much more important difference between us and foreign countries is wrought into the very texture of our society; it is that generally pervading freedom from restraint, in matters like those I have just specified. In England, it is said that forty days undisturbed residence in a parish gives a journeyman mechanic a settlement, and consequently entitles him, should he need it, to support from the poor rates of that parish. To obviate this effect, the magistrates are on the alert, and instantly expel a new comer from their limits, who does not possess means of giving security, such as few young mechanics command. A duress like this, environing the young man, on his entering into life, upon every side, and condemning him to imprisonment for life on the spot where he was born, converts the government of the country,—whatever be its name,—into a despotism.

Such is the condition of mechanics abroad; such, thanks to our free institutions and the

bounty of a good Providence, is not the condition of mechanics here. They may—in fact they must neglect the cultivation of their minds; but the American mechanic is inexcusable if he neglects the great privileges which distinguish him from the less fortunate European.

Another reason why the American mechanic should cultivate his intellectual powers as far as possible, is the vastly wider field which is opened to him by the extent and the resources of his country, and the ever active enterprize of its citizens. The European mechanic is hedged in on every side by restriction, and by competitors without number. All the trades there are full. In our country we see the reverse. Here we have not men enough to perform the work required. The demand for mechanical industry has never been fully met, and cannot be, for a long time to come. The immense amount of our land, the preponderance of agricultural industry, and the increasing demands of commerce, open an unlimited field to mechanical enterprise. We may infer what may yet be done from what has already been done. The service which the mechanical ingenuity of Americans has already rendered to

the country is at once a source of pride and of hope. Take, for example, the service rendered to the cotton growing interest by Whitney's invention of the saw-gin; or that rendered to internal commerce and to agriculture by Fulton's introduction of the steamboat into general use; or that rendered to every consumer in the country by inventors and manufacturers concerned in the production of cotton and woollen fabrics. These inventions and improvements, by increasing the resources of the country, have greatly increased the demand for mechanical products. Whether, therefore, the American mechanic addresses himself to increasing the quantity or improving the quality of his manufactures, the field before him is wide enough for his greatest powers and his most unwearied activity. In entering upon this field, let him remember that knowledge is power, and he will neglect no opportunity of impr ing his mind.

CHAPTER VII.

MEANS OF INTELLECTUAL CULTIVATION ACCESSIBLE TO THE MECHANIC.

Supposing that the reasons why an American mechanic should be well educated are sufficiently established, let us next consider the means which are at his disposal or may be brought within his reach.

1. Of course the first and most important means of intellectual cultivation are the schools; and those to the improvement of which the efforts of mechanics as a body can be most serviceably directed are the *public* schools. Wherever a system of public schools exists, it is the interest of the mechanic, in common with all other citizens, to aid in rendering it as perfect as possible. I believe that it is essential to the perfection of a system of public schools, that not only elementary instruction should be dispensed to the children of all citizens who require it; but that schools of a higher order should be placed within the reach of all pupils whose parents may wish to obtain

the advantages of higher instruction for their offspring. Experience shows that it is not a difficult matter to create a supply of this higher instruction equal to the demand, even where the provision of primary instruction is most abundant. In Boston, where the population is over eighty thousand, and the primary and grammar schools are sufficient to accommodate every applicant for admission without delay, the High School for twenty years has averaged only ninety pupils; this being the whole number of qualified candidates offered for admission.

In Philadelphia the supply has certainly been hitherto equal to the demand, as all applicants for admission to the High School who were qualified for the higher studies at the time of their examination have been admitted. I believe that the number of scholars who will leave the school every year to enter upon the active business of life, will always be found equal to those who shall be qualified for admission and shall present themselves for examination. The advantages resulting from High Schools are not confined to the pupils who receive instruction at those schools. The stimulus afforded by the hope of attaining admission

to them acts upon all the other schools, producing greater exertion and a more rapid progress in learning. In fact the whole system is not only improved, but greatly extended, by the existence of higher classes of schools. This is apparent in this city,* where a greater number of primary and grammar schools have been created since the erection of the High School than at any previous period of the same length. The High School furnishes to the future mechanic precisely the liberal kind of instruction which will be most available to him in his trade; and in some instances gives minute practical information directly applicable to the arts; as for example, in the mathematical and drawing lessons, and the lessons, lectures and experiments on chemistry, natural philosophy and natural history; other parts of the course of instruction, as the training in logic, rhetoric and composition, have more direct reference to the pupil's future position in the community as a citizen, a public officer, a parent, or a teacher. Such institutions it is the interest of every man to sustain; of the rich, who do not avail themselves of this advantage for their own children,

* Philadelphia.

equally with those who are not rich, and therefore need their aid. In fact, the laws which distribute property equally among heirs, render it probable that the grand-children, or great-grand-children of the richest man in any of our communities will become pupils in the public schools. It is, therefore, the rich man's interest to pay heavy taxes, if need be, in order that the public schools may be rendered perfect. 2. The inheritance which he will thus transmit to his posterity. will last long after his wealth shall have been scattered to the winds I pass with reluctance from this interesting part of the subject, to the next means of intellectual improvement for the mechanic, viz.: the Mechanic's Institute. Any youth who has been taught to read and write, may derive advantages from the lectures, experiments and library of the Mechanic's Institute; and the system of operations in these admirable institutions is so liberally expanded, that the most accomplished scholar may also increase the amount of his practical knowledge by having recourse to the means of improvement which they afford. 3. But the best of all instruction is self instruction, and the most available means which the young man who is determined to

instruct himself can employ, are the library and the apparatus which are immediately at his own disposal—under his own roof—in his own apartment. The great secret of self improvement is to dedicate a portion of every day to private study. Consult the biographies of a long line of self taught men who have advanced science and the arts by their individual exertions, and you will find in most instances that the brilliant discovery which astonished the world was the result of private study and unassisted experiment. You will find also that the hour redeemed from ordinary business, and consecrated to some favourite scientific inquiry, was the great discoverer's choicest recreation, the delight of the day, the great reward of many labours and cares. We all have our favourite enjoyments, apart from our daily labour. While one man *reads* for recreation, another plays upon the flute or takes a ride, or sketches a landscape, or talks politics, or tells stories to his children. All these amusements are excellent and refreshing in their season—all are looked forward to with pleasure; but a sweeter recreation than any of these awaits the man who is at once a hard worker and a devotee of science. Often in the course of a busy day do

his thoughts bound forward to the happy moment when he shall enter the sanctuary of his own study, leaving his toils and cares behind, and, "the world forgetting, by the world forgot," shall busy himself in his favourite pursuits, studying, experimenting, calculating, till his brain is weary with pleasurable excitement, and tired nature claims the right of repose. In order to profit by study it is not absolutely necessary, but it is certainly very convenient and agreeable to have a place, a room, be it ever so small or so poorly furnished, which the student, the self instructer, may call his own—his castle—his sanctuary. Here he treasures up his little library of books, few perhaps, but choice and well beloved. Here he has his desk, papers, and his collection of curious or useful things, each fraught with associations, each the occasion of a lesson to himself. The mineral, which is but a common pebble to the visitor who comes in to look at his cabinet, has a magic power in it for the collector himself. It brings back to his recollection the glorious mountain towering to the skies—the cataract—the deep cavern, or the broad prairie, where the wonderful gem was found—wonderful by the power of association which it has over the mind

of its finder. The well worn volume, which is mere paper and print to another, is a precious treasure to him, who has learnt from it the great laws of nature, the lore of antiquity, or the sweets of poetry. Every article in this retreat of studious leisure has a value to the owner, as it is connected with the developement of his higher faculties. Every article is praised for having been, in its turn, the instrument of self cultivation. It would occupy too much time to enter here into a detailed review of the various means of self cultivation to which the student may have recourse in the retirement of his own room. These will form the subject of a future chapter.

CHAPTER VIII.

REWARDS OF INTELLECTUAL CULTIVATION ACCESSIBLE TO THE MECHANIC.

I WILL now offer a few remarks on the *rewards* of intellectual cultivation. Liberal knowledge, like virtue, is in a certain sense its own reward. The developement of the intellectual powers is attended with positive gratification, resulting from a sense of increased power, and the satisfying of curiosity respecting the laws of nature. The famous story of the rapture of Archimedes when he arrived at his beautiful demonstration of a well known mathematical truth, is but one among a thousand proofs that science rewards her votaries on the instant, pays her workmen, in solid coin, by the day—by the hour. This is the sweetest and best reward of intellectual labour. It is that which is most diligently sought and most highly prized.

But there are other rewards, only incidental and inferior, but still worthy of some consideration.

1. Liberal knowledge and accomplishments confer the advantage of an elevated and influential position in society. It is generally understood that society exacts from each of its members some price of admission to its coteries and saloons. One brings fashion, another the wealth and consequence of his family, another his musical or conversational talents, another his celebrity as an author or traveller, or distinguished stranger. Among the rest the votary of science prefers his claim, and finding it admitted, takes a place in society on an independent and respectable ground. He is admitted for what he *is*, not for what he *has*, or what his ancestors *had*.

2. Again, liberal knowledge gives its possessor the means of enjoyment in sickness, in retirement, and in old age. He who has learnt to converse with the master spirits of other times, is never at a loss for society or amusement. Give him a book and he is happy—or, failing the book, his previous cultivation makes the communion of his own thoughts or the practice of composition a sufficient occupation to pass delightfully those hours of loneliness and silence which are a weariness to the illiterate man.

3. To the advantages which the scientific mechanic enjoys in the prosecution of his trade we have already adverted. We will name but one more before closing the present consideration of the subject. It is this :—The members of any particular trade, by earnestly uniting in the use of the various means of intellectual cultivation within their reach, may greatly increase the respectability, wealth and influence of that trade. By possessing their own library, reading room, museum and apparatus, and by stimulating the exertions of every member of the trade, master, journeyman, and apprentice, they will soon come to be recognised as a scientific body; and will not only insure to themselves the other rewards of science, but will receive the grateful acknowledgments of their fellow citizens as public benefactors.

Such are the rewards of intellectual cultivation attainable by those who are engaged in the mechanical trades. The example of Franklin, Watt, Arkwright, and a host of other illustrious men, show what mechanics *have* done. It remains for the rising generation in our own happy land to show what mechanics *can* do.

CHAPTER IX

THE MECHANIC'S STUDIES.

Books are, generally speaking, too voluminous; writers descend too much into minutiæ; and it is an old observation, that where men are determined to write every thing which can be said on any subject, they may write to eternity. Hence it is that a man of sense and erudition need but open a single page of many a modern volume to lay it aside forever. It is said of Didymus, an ancient grammarian, that he had written so much that he knew not his own productions, and having once abused a work for its absurdity, it was found to be his own. I fear the race of Didymus is not extinct.*

To read all books on all subjects would require an uninterrupted attention during the longest life, even of an antediluvian. To read only the most celebrated, written in a few languages, is an employment sufficient to fill up every hour of laborious application. For the

* Northmore.

sake then of saving time, and of directing the judgment of the inexperienced, it becomes an useful attempt to suggest some general hints, which may tend to facilitate selection. One rule of the greatest consequence is, to read only, or chiefly, the original treatises in all the various departments of science or of literature. Nearly the same space of time, though not the same degree of attention, is necessary to peruse the faint copies of imitative industry, as would appropriate to the student the solid productions of native genius. This rule is more particularly to be observed on the first entrance on study. The foundation must be laid deeply, and formed of solid materials. The superstructure will often admit slight and superficial appendages. When we have studied the fine relics of those who have lived before us, we may derive much pleasure from attending to the additional labours of contemporary genius. But to begin with these is to found, like the fool recorded in the gospel, an edifice in the sand.*

The merit of a book consists in, 1, New facts; 2. New inferences from established facts;

* Knox's Essays.

3. A better arrangement; 4. A more complete collection of facts; 5. Information. When a book is destitute of these requisites, it may be condemned, without mercy, as of no use whatever, and immediately sold by weight to the cheesemonger, or consigned to any other base or more ignoble purpose. When it is not destitute of these, it should be reprieved, acquitted, or applauded, according to the requisites which it possesses.*

On the choice of books, most excellent advice is given by Dr. Watts, from whom, and other authors, has been compiled a pocket volume "on the Improvement of the Mind," in which various interesting matter relating to books, reading, conversation, study, &c. are treated of. Happy are they, says Fenelon, who being disgusted with all violent pleasures, know how to content themselves with the sweets of an innocent life. Happy are they, who are diverted, at the same time that they are instructed, and please themselves by enriching their minds with knowledge. Where-ever they may be thrown by adverse fortune, they will carry their own entertainment with

* Dr. Mosley.

them; and the uneasiness, which preys on others, even in the midst of their pleasures, is unknown to those who can employ themselves in reading. Happy are they who love books and are not deprived of them.

Among the other improvements of the present age, the art of puffing appears to have arrived at such perfection that it is impossible to select books by their titles, or from some of our booksellers' account of them in their advertisements. A person who would make a preference and choose the best, must read much beyond the title page. From a hand bill which accidentally lies on the compiler's desk, the following encomiums are bestowed on very immethodical and inferior works. "A fascinating introduction, superior to every preceding attempt of the kind, and deserving of universal preference." "The most approved and generally adopted book ever published, and undoubtedly the best extant." Such parade of applause may pass with those who do not compare and discriminate, and their number is unfortunately not small.

Mr. Pratt ingeniously laments the strange circumstance, that authors themselves have been the most bitter detractors of the talents

and reputations of each other. A grievance far more disgraceful, if not more injurious, to the literary character, than any other species of criticism. Indeed it would be difficult to find any set of enemies among men, any persons, whose passions and interests are at variance, so full of acerbity, of open violence, or of concealed malice, as the most eminent writers have proved themselves to each other, in their contentions of rivalry. The "republic of letters" is a very common expression among Europeans, and yet, when applied to the learned of Europe, is the most absurd which can be imagined, since nothing is more unlike a republic, than the society which goes by that name In truth, almost every member of this fancied commonwealth is desirous of governing, and none willing to obey: each looks upon his fellow as a rival, not an assistant in the same pursuit. They calumniate, they injure, they despise, they ridicule, they worry, and assassinate each other. If one man write a book which pleases, others write books to show that he might have given still greater pleasure, or should not have attempted to please. If one happen to hit upon something new, numbers are ready to assure the public that all this was

no novelty to them or the learned; that Cardanus, or Brunus, or some other author, too dull to be generally read, had anticipated the discovery. Their jarring constitution, instead of being styled the republic of letters, should be entitled the *anarchy* of literature. It is true, there are some of superior abilities, who reverence and esteem each other; but their mutual admiration is not sufficient to shield off the contempt of the crowd. The wise are but few, and they praise with a feeble voice; the vulgar many, and roar in reproaches. The truly great seldom unite in societies, have few meetings, and no cabals: the dunces hunt in full cry, till they have run down a reputation, and then snarl and fight with each other about dividing the spoil." No task would be more easy to the most superficial observer, than that of producing numerous instances of glaring partiality in the journals of several of our critics by profession. . It appears sometimes from their neglect in reading with care the book which they undertake to criticize, so as to comprehend the author's views; sometimes the narrowness of party spirit warps their decisions, in open contempt of the power of genius and originality. Sometimes a publisher's name on

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the cover, connected with the imprint of the book, is a clue by which neglect, injustice, narrow-minded selfishness, and misrepresentation, may be unravelled; and sometimes the critic's private pique, as a contemporary author, is obvious.

Poetic compositions, whether in ancient or modern languages, may be read at vacant hours, with some advantage, because many passages contain practical rules relating to moral economy and religion. Many elegant and ingenious sentiments and descriptions may also be found among the writings of poets, well worth committing to memory; and the measure of verse greatly assists recollection.

The mere art of rhetoric never yet formed an English orator. It is one of those artificial assistances of genius, which genius wants not, and of which dullness can little avail itself. But as excellent books have been written on this subject, the general scholar will not fail to pay it some attention. Let him then read Cicero on the Orator, and Quintilian's Institutes, and he need not trouble himself with those meagre treatises which give a hard name to natural modes of expression, and teach us that, like Hudibras, we cannot open our mouths,

but out there flies a trope.* So much of rhetoric as teaches the art of speaking and writing with elegance and dignity, in order to instruct, persuade and please, is certainly most valuable. Grammar teaches only propriety; but rhetoric raises upon it purity and clearness of language, elegant thoughts, variety of expression, and lively figures. The duty of the orator is to state interesting truths with such probability and evidence as may gain belief, and with such force and simplicity as may produce conviction. He must be able to demonstrate, to delight, and to work on the passions.

Probably nothing has contributed more to generate apposite habits of mind than the early taste for reading. Books gratify and excite our curiosity in innumerable ways. They force us to reflect. They hurry us from point to point. They present direct ideas of various kinds, and they suggest indirect ones. In a well written book we are presented with the maturest reflections, or the happiest flights, of a mind of uncommon excellence. It is impossible that we can be much accustomed to such companions, without attaining some resemblance of

* Dr. Knox.

them. He who revels in a well chosen library, has innumerable dishes, and all of admirable flavour. His taste is rendered so acute, as to distinguish the nicest shades of difference. His mind becomes ductile, susceptible to every impression, and gains new refinement from each. His varieties of thinking baffle calculation, and his powers, whether of reason or imagination, become eminently vigorous.*

Exclusive of all regard to interest, and of preparation for the exercise of any art or profession, says Dr. Knox, a taste for pleasing books is surely eligible, if it were only for the sake of enabling an ingenious man to pass his days innocently, calmly, and pleasurably. The pleasures of letters are certainly great to those who have been early devoted to them, and they are of all others the easiest to be obtained. For with respect to books we may say, "These are friends, no one of whom ever denies himself to him who calls; no one takes leave of his visitor till he has rendered him happier and more pleased with himself. The conversation of no one of these is dangerous, neither is the respect to be paid to him attended with expense.

* Godwin's Enquirer.

You may take what you please from them. What happiness, what a glorious old age awaits him who is placed under the protection of such friends! He will have those whom he may consult on the most important, and the most trifling matter, whose advice he may daily ask concerning himself; from whom he may hear the truth without insult, praise without adulation, and to whose similitude he may conform himself."*

As soon as we have obtained, by reading, a competent knowledge of a book or particular subject, it will contribute greatly to animate us in proceeding still farther, if we talk of it either with our equals in attainments, or with the learned and experienced. In such conversation we venture to advance an opinion; our self-love renders us solicitous to maintain it, we seek the book as an auxiliary, we therefore read it with eager attention. In this manner an attachment to books and literary employments is gradually formed, and what began in labour or necessity, becomes a choice, and constitutes the most agreeable pleasure.

There is no study so dry, but by fixing our attention upon it, we may at last find it capa-

* Seneca.

ble of affording great delight. Metaphysics and mathematics, even in their abstrusest parts, are known to give the attentive student a very exalted satisfaction. Those parts, then, of human learning, which in their nature are more entertaining, cannot fail of being beloved in a high degree, when the mind is closely and constantly applied to them.

In order to acquire the power and habit of fixing the attention, it will be first necessary to summon a very considerable degree of resolution. In beginning the study of a new language, or any book of science, which presents ideas totally strange, the mind cannot but feel some degree of reluctance or disgust. But let the student persevere; and in a very short time the disgust will vanish, and he will be rewarded with entertainment. Till this takes place, let him make it an inviolable rule, however disagreeable, to read a certain quantity, or for a certain time, and he will infallibly find, that what he entered upon as a task, he will continue as his best amusement.

A due degree of variety will contribute greatly to render reading agreeable. For though it be true that not more than one or two books should be read at once; yet, when finished, it

will be proper, if any weariness be felt, to take up an author who writes in a different style, or on a different subject; to change from poetry to prose, and from prose to poetry; to intermix the moderns with the ancients; alternately to lay down the book and take up the pen; and sometimes to lay them both down, and enter with alacrity into agreeable company and public diversions. The mind, after a little cessation, returns to books with all the voracious eagerness of a literary hunger. But the intermissions must not be long, or frequent enough to form a habit of idleness or dissipation.

The morning has been universally approved as the best time for study; but at all hours and in all seasons, if we can restrain the licentious rovings of imagination; soothe the passion of the heart, and command our attention, so as to concentre it on the subject we examine, we shall find it amply rewarded. Attend closely; and close attention to any worthy subject will always prove solid satisfaction. But particularly in reading it may be depended on as approved truth, that the degree of profit as well as pleasure, derived from it, will ever be proportioned to the degree of attention.*

* Knox's Essays, No. 82.

There are some mechanic aids in reading, which may prove of great utility. Montaigne placed at the end of the book which he intended not to reperuse, the time he had read it, with a concise decision on its merits. He has obliged his admirers with giving several of these annotations. The striking passages in a book may be noted on a blank leaf, and the pages referred to with a word of criticism. Seneca, in sending some volumes to his friend Lucilius, accompanied them with notes on particular passages, that, as he observes, you who only aim at the useful, may be spared the trouble of examining them entirely. I have seen books noted by Voltaire with a word of censure or approbation on the page itself, which was his usual practice; and these volumes are precious to every man of taste.*

I would have every one try to form an opinion of an author himself, though modesty may restrain him from mentioning it. Many are so anxious to have the reputation of taste, that they only praise the authors whose merit is indisputable. I am weary of hearing of the sublimity of Milton, the elegance and

* D'Israeli's Miscellanies.

harmony of Pope, and of the original, untaught genius of Shakspeare. Such hackneyed remarks are made by those who know nothing of nature, and can neither enter into the spirit of those authors, nor understand them.*

Temperance in eating and drinking, will contribute more to improve the natural force or abilities of the mind, than any art or any application. It is related of the unfortunate young Chatterton, that he was remarkably abstemious, and that it was a frequent and favourite maxim with him, that a man might arrive at any height of improvement, or effect the most arduous undertaking, by dint of industry and abstinence. He practised what he thought; and this in some degree accounts for his uncommon attainments and productions, at an age when the full-fed heir can scarcely read and write. I recommend to all students the perusal of Dr. Cheney's Medical Advice; or I will give it to them in a few words. "Take the least and the lightest food, under which you can be easy." Your soul will thus feel fresh vigour, your life will be longer and happier, and your conduct wiser.†

The neglect of writing in early life is the

* Mary Wollstonecraft. † Dr. Knox.

reason that almost every line of our scholars and gentry (who seem to pride themselves in their bad penmanship) stands in need of an interpreter. As this art is purely mechanical, and perfected by practice only, it is foreign from my purpose to prescribe rules for its attainment. I will venture however to assert, that a plain, upright hand, resembling the round roman print is preferable to the ridiculous flourishes and slopes of writing-masters; and my opinion is founded on a very simple reason, it is more legible.*

Plain writing, says Dr. Gregory, clear of flourishes, and very upright, is certainly the most proper for every station of life, and will remain intelligible longer than any other. It may be learned with less time and trouble, and may be written more expeditiously. I have long been of this opinion, and was happy to find it countenanced by the authority of Dr. Knox, and Dr. Beattie. Their popularity may perhaps be of weight in correcting the whimsical and unintelligible mode of writing, which has been introduced by ignorant schoolmasters. I perfectly agree with the latter, that the writing

* Yorke.

which approaches nearest the Roman printed character, is the completest. Pope was taught to write by imitating and copying the Roman character of printed books, in which kind of writing he always excelled. [The *Italic* printed character appears better adapted for the purpose of writing than the Roman.] A gentleman informed, by letter, his country friend in Lincolnshire, who had done him some recent favour, how much he was obliged, and that he should soon send him an *equivalent.* Not being accustomed to *fashionable* scrawls, he read it that his friend would send him an *elephant*, and, building a barn at the time, actually fitted up a stall for the reception of his expected present. The arrival, however, of a barrel of oysters, a few days afterwards, helped him to the right reading, by putting him in possession of a more suitable equivalent than an elephant. This is a fact, and occurred a few years since.*

* Rede's Anecdotes, 1799.

CHAPTER X.

THE MECHANIC'S STUDIES.

To learn the rudiments of grammar by rote, is not the way to understand grammar. The *mind* must be addressed and convinced. Of what use is it to vex a boy's memory with the definition of a noun, when the definition itself is not clear to his understanding? We may as well show him the figure of a triangle on paper, and expect him to comprehend its nature, by a definition of its properties. The fact is, the tender mind is not capable of abstract reasoning; consequently, every subject which implies the generalization of ideas, should be first unfolded by evident and palpable demonstration. Thus, a boy is taught in our schools to gabble that "a noun is the name of any person, place, or thing, as John, London, Honour;" yet I will venture to assert, that not one in ten thousand comprehends what he says. An analysis of language was never formed, until men were enabled to observe the turns of speech which custom authorizes; there were

poets and orators before a grammar was ever thought of; it would be useless to teach either systems of rhetoric or composition to a child, who had not learnt, by frequent use, the proper idioms of his own language; and that therefore the best models of beautiful writing should be set before him, previous to his being brought to judge of them by any determined rules.*

If grammar be taught, it must be to one who can speak the language; how else can he be taught the grammar of it? This is evident from the practice of the wise and learned nations among the ancients. They made it a part of education to cultivate their own, not foreign tongues. The Greeks counted all other nations barbarous, and had a contempt for their languages. And though the Greek learning grew in credit among the Romans, towards the end of their commonwealth, yet it was the Roman tongue which was made the study of their youth. It was their own language which they were to make use of, and therefore it was their own language they were instructed and exercised in.

But more particularly to determine the pro-

* H. R. Yorke.

per season for grammar, I do not see how it can reasonably be made any one's study, but as an introduction to rhetoric. When it is thought time to put any one on the care of polishing his tongue, and of speaking better than the illiterate, then is the time for him to be instructed in the rules of grammar, and not before: for grammar is designed not only to teach men to speak, but to speak correctly, and according to the exact rules of the tongue, which is one part of elegancy; there is little use of the one to him who has no need of the other; where rhetoric is not necessary, grammar may be spared.*

The cumbersome heap of worthless rules with which grammars are crowded, has urged some into the extreme of discarding them. They have observed that a quicker progress has been made in a language by learning it by mere rote, and from thence have extravagantly concluded that grammars are unnecessary. Without the assistance of the rules of construction, it is difficult to speak the living languages well; to say nothing of reducing science to principles, which contribute to form

* Locke.

the judgment. But grammars ought to be constructed rationally, whereas many, so far from being adapted to the capacities of children, suppose them to be half philosophers in the outset. This is evident from the connection which the rules have with things with which children are unacquainted.*

With a view of making the study of language agreeable and pleasant, particularly to boys, it is necessary that the subject on which students are employed to read, be interesting. The judicious teacher can easily collect authors, in almost every language, whose writings are calculated to arrest and interest the mind at an early period of life. In order, however, to render the study and comprehension of such works easy, difficult passages should always be satisfactorily explained in the student's vernacular tongue, by notes; and they should, for beginners, be accompanied with literal translations.†

Two things are requisite in learning a language; a knowledge of words, and skill in putting them together in writing or speaking. The former is much the more easy of the two,

* De l'Education par M. de Crousaz. † Dr. Cowan.

and consequently ought to go first: to intermix any foreign stuff, as grammar with it, is throwing an obstacle in the way of boys, and hindering their progress. They are to be kept to but one thing at a time, as much as possible To trouble them with variety, unless by way of refreshing their memories, or to prevent their forgetting what they have already learnt, I think a grand mistake in education, and one main occasion of that miserable work which boys make of it in most schools.

Though grammar be a matter of importance, the parts of language which relate to the signification of words, and phraseology are of greater importance. In the latter departments, a pupil cannot be overburdened; in the former, there are many things not worth committing to memory; and he who intends to make a boy a critic in grammar, will unavoidably leave him deficient in other more necessary things. It would be the same as if a man should take care to let his son be furnished with elegant shoes, while the rest of his body was clothed in rags.*

I very much doubt whether any child, pro-

* Clarke's Essay on Education.

digies excepted, be capable of learning two languages, till it arrive at the age of twelve or thirteen. I have indeed seen little wonderful prattlers, who were imagined to talk five or six different languages. I have heard them successively talk in German, in Latin, French, and Italian words. They made use, it is true, of the different terms of five or six dictionaries; but they spoke nothing but German. In a word, fill a child's head with as many synonymous terms as you please, you will change his words only, but not his language, for he can know but one. No sooner have they gone through the rudiments of the grammar, of which they absolutely understand nothing, than they are set to render a discourse spoken in their native tongue into Latin words; when they are advanced a little farther, they are engaged to patch up a theme in prose, by tacking together the phrases of Cicero, and in verse with centos from Virgil. They then begin to think themselves capable of talking Latin. And who is there to contradict them.*

To learn a language grammatically, or even to speak it, allowing for bad pronunciation, is

* Rousseau, b. 2.

at any time of life an easy acquisition. We are told that Themistocles learnt the Persian language in one year, and a year is sufficient time to learn any language. It is too great an attention to the rules of grammar which retards our improvement. Rousseau has therefore properly warned us against correcting the grammatical errors of children, who never fail in due time to correct themselves. Mr. Locke recommends the same method to be adopted in learning the dead languages. "The Latin tongue," he observes, "would easily be taught, if the tutor being constantly with his pupil would talk nothing else to him, and make him answer still in the same language." But to this reasoning I object; for, not to mention the difficulty of finding tutors who can speak these languages well, it is the constant daily habit of conversing *with every one around us*, which facilitates the acquisition of living tongues, and this is particularly the case with children, who learn more in one hour's game of play with their equals, than in a day's discourse with their tutors. Another strong objection to this method arises from its inutility. The only use of learning the dead languages is, as Milton says, to "study the solid things in them." Now even allowing

that a pupil may be competent to hold a conversation in Latin, which certainly is making a great allowance, if we take into consideration the difficulty of applying an ancient language to modern customs, yet he will reap but little benefit from this acquisition when he comes to read the philosophic works of Cicero, or Quintilian, or the histories of Livy or Tacitus. The same reasoning is in some measure applicable to modern tongues. A foreigner who can speak English well, may be unable to comprehend either the sublime beauties of Shakspeare, or the nervous eloquence of Johnson. But though I dissent from Mr. Locke as to the best means of acquiring the dead languages, yet of the method which I am now about to propose, I speak with the greater confidence, being supported in my opinion not only by my own experience, but by the practice of Roger Ascham, the celebrated tutor to Queen Elizabeth. The custom established in schools of obliging the scholars to learn the grammar by heart, cannot be too much deprecated. The grammar, like the dictionary, is only a book of reference; "to read it therefore by itself, is," as Ascham well observes, "tedious for the master, hard for the scholar, cold and uncomfortable for them both."

It certainly is irksome for boys who have it to learn, because it conveys no pleasurable ideas, and much time is thus unnecessarily lost. Mr. Dyer in his life of Robinson, has observed that "Mr. Robinson's way of acquiring a knowledge of languages, was to sit down to an author, without any previous knowledge of the grammar, and to refer only to it in the same manner as the dictionary." This being premised, let us now suppose that my pupil is to be instructed in the Greek language. He accordingly procures a grammar and dictionary; but instead of labouring a twelvemonth in committing the former to memory, he reads it over once or twice merely to acquire some little insight into the nature of the language. His tutor then procures for him the best work of the purest Greek writer; suppose the Republic of Plato, or the Cyropædia of Xenophon, which is better adapted to youth. We now sit down together, with our pens, ink and paper, to translate one of the easiest passages, making due reference to our grammar and dictionary. Having done this we shut our books, and put our translations carefully by in our drawers. We then proceed to other business; perhaps to the carpenter's chest, or the garden tools. The

next morning we take out our translations, and retranslate them into the best Greek we are able, which we compare with, and correct by the original text. This translation and retranslation, increasing gradually in quantity, we continue to practise, till we become masters of the language, never omitting a single day, how small soever be the portion. It should be remembered, that, as we increase in knowledge, the version of one day is not retranslated till the interval of three or four days has elapsed, in order that the pupil may not translate by rote. By these means the language is learnt not only with greater facility, but to much greater perfection; for the scholar acquires a knowledge of the peculiar cast of the language, and the particular points in which it differs from his own. Another advantage attending this system of translation, is, that the pupil cannot suffer from the ignorance of his tutor, both of them having the best possible standard for their guide. Nor perhaps is it a matter of small importance that the tutor is improving himself, at the very time that he is instructing his pupil; and I am certain that the appearance only of studying one's-self, tends much to increase the love of study in youth.

In addition to translating, we must not omit to mention the advantages which accrue, particularly to maturer minds, from reading and reciting the works of the great masters. By this we imbibe not only a taste for their purity and elegance of diction, but frequently participate of their animation, and the fire of their genius.*

Let none despair of acquiring, not only a competent but a critical knowledge of language, at whatever age a taste for such studies may be imbibed. Julius Scaliger, a profound critic, knew not the letters of the Greek alphabet at the age of forty years. Dr. Franklin learnt to speak French when upwards of seventy. Eugene Aram, without any assistance, learnt Latin, Greek, Hebrew, French, Chaldee, Arabic, and the Celtic.

Whatever be the advantages, or defects of the English language, as it is our own language, it deserves a high degree of our study and attention, both with regard to the choice of words which we employ, and with regard to the syntax, or the arrangement of these words in a sentence. We know how much the Greeks and the Ro-

* Northmore.

mans, in their most polished and flourishing times, cultivated their own tongues. We know how much study both the French and the Italians have bestowed on theirs. Whatever knowledge may be acquired by the study of other languages, it can never be communicated with advantage, unless by such as can write and speak their own language well. Let the matter of an author be ever so good and useful, his compositions will always suffer in the public esteem, if his expression be deficient in purity and propriety. At the same time, the attainment of a correct and elegant style, is an object which demands application and labour. If any imagine they can catch it merely by the ear, or acquire it by a slight perusal of some of our good authors, they will find themselves much disappointed. The many errors, even in point of grammar, the many offences against purity of language, which are committed by writers who are far from being contemptible, demonstrate, that a careful study of the language is previously requisite, in all who aim at writing it properly.*

The application of a child to a dead lan-

* Dr Blair.

guage, before he be acquainted with his own, is a lamentable waste of time, and highly detrimental to the improvement of his mind. The general principles of grammar are common to all languages; a noun is the same in English, French, Latin, Greek, &c. The varieties of languages are easily acquired by observation and practice, when a preliminary knowledge of our own grammar is obtained. But, the comprehension of our native tongue, is not the only good preparative for the study of other languages. Some previous acqaintance with the general nature of things is necessary to the accomplishment of this end, in order that our literary progress may not be obstructed merely by words. For, although it be useful to leave some difficulties in the way of a child, that he may exercise his mind in overcoming them, yet he must not be disgusted by too many or too great impediments. Our whole attention should consist in proportioning the difficulties to his powers, and in offering them to his consideration individually. If Latin were made the pri mary object of a child's lesson, he would lose a vast portion of time in the study of grammar; he would be incapable of perceiving the beauties of that language, because he would not

have acquired any previous knowledge. No benefit therefore could possibly accrue, from reading in the Latin tongue subjects which he could not understand in his own. But, by his becoming well acquainted with our best poets and prose writers, he will easily learn, independently of the number of ideas which he will gain thereby, the general rules of grammar; several examples will unfold them, and a proper application of others may be soon made without difficulty. Besides, he will acquire taste and judgment, and be well prepared to feel the beauties of a foreign tongue, when he begins to feel the beauties of his own. His knowledge being also extended and diversified, it will be found that the sole difficulty attendant on the study of Latin, consists in learning words; so that to obtain a just knowledge of things he must apply himself to such Latin authors only as are within the reach of his capacity, and whose writings he can comprehend with the same facility as if they were written in his native language. By this plan, he will easily acquire the Latin tongue, treasure up fresh knowledge as he advances, and experience no disgusts in the study of it. Nothing can be more useless than to fatigue a

child, by filling his memory with the rules of a language which he does not yet understand. For, of what advantage is the knowledge of its rules, if he be unable to apply them? We should wait, therefore, until reading has gradually enlightened his mind, and the task becomes not irksome to him. When he has studied his own language, we should anticipate the principal difference between the Latin and English syntax. His surprise in perceiving an unexpected difference, will excite his curiosity, and effectually remove all distaste. After this, and not before, we may devote a part of each day to Latin; but it ought never to be the first object of his studies.* The best English Grammar for the purpose of self instruction is Frost's Practical Grammar, published by Thomas, Cowperthwait & Co., Philadelphia.

The Latin authors are possessed of uncommon excellence. One kind of excellence they possess which is not found in an equal degree in the writers of any other country: an exquisite skill in the use of language; a happy selection of words; a beautiful structure of phrase; a transparency of style; a precision

* H. R. Yorke.

by which they communicate the strongest sentiments in the directest form; in a word, every thing which relates to the most admirable polish of manner. Other writers have taken more licentious flights, and produced greater astonishment in their readers. Other writers have ventured more fearlessly into unexplored regions, and cropped those beauties which hang over the brink of the precipice of deformity. But it is the appropriate praise of the best Roman authors, that they scarcely present us with one idle and excrescent clause, that they continually convey their meaning in the choicest words. Their lines dwell upon our memory; their sentences have the force of maxims, every part vigorous, and seldom any thing which can be changed but for the worse. We wander in a scene where every thing is luxuriant, yet every thing vivid, graceful and correct.

It is commonly said, that you may read the works of foreign authors in translations. But the excellencies above enumerated are incapable of being transfused. A diffuse and voluminous author, whose merit consists chiefly in his thoughts, and little in the manner of attiring them, may be translated. But who can translate Horace? who endure to read the transla-

tion? Yet who is there, acquainted with him only through this medium, but listens with astonishment and incredulity to the encomiums he has received from the hour his poems were produced? The Roman historians are the best which ever existed. The dramatic merit and the eloquence of Livy; the profound philosophy of Sallust; the rich and solemn pencil of Tacitus, all ages of the world will admire. Add to this, that the best ages of Rome afford the purest models of virtue which are any where to be met with. Mankind are too much inclined to lose sight of all which is heroic, magnanimous and public spirited. Modern ages have formed to themselves virtue, rather polished than sublime, which consists in petty courtesies, rather than in the tranquil grandeur of an elevated mind. It is by turning to Fabricius, and men like Fabricius, that we are brought to recollect what human nature is. Left to ourselves, we are apt to sink into effeminacy and apathy. It is by comparison only that we can enter into the philosophy of language. It is by comparison only that we can separate ideas, and the words by which those ideas are ordinarily conveyed. It is by collating one language with another that we detect all the

shades of meaning through the various inflections of sense which the same word suffers, as it shall happen to be connected with different topics.

He who is acquainted with only one language, will probably always remain in some degree the slave of language. From the imperfectness of his knowledge, he will feel himself at one time seduced to say what he did not mean, and at another time will fall into errors of this sort without being aware of it. It is impossible he should understand the full force of words. He will sometimes produce ridicule where he intended to produce passion. He will search in vain for the hidden treasures of his native tongue. He will never be able to employ it in the most advantageous manner. He cannot be well acquainted with its strength and weakness. He is uninformed respecting its true genius and discriminating characteristics. But the man who is competent to, and exercised in the comparison of languages, has attained to his proper elevation. Language is not his master, but he is the master of language. Things hold their just order in his mind; ideas, first, and then words. Words therefore are used by him as the means of communicating

or giving permanence to his sentiments; and the whole magazine of his native tongue is subjected at his feet.

Latin is a language which will furnish us with the etymology of many of our own words; but it has perhaps peculiar recommendations as a praxis in the habits of investigation and analysis. Its words undergo an uncommon number of variations and inflexions. These inflections are more philosophically appropriated, and more distinct in their meaning, than the inflections of any language of a more ancient date. As the words in Latin composition are not arranged in a philosophical or natural order, the mind is obliged to exert itself to disentangle the chaos, and is compelled to yield an unintermitted attention to the inflections. It is therefore probable that the philosophy of language is best acquired by studying this language. Practice is superior to theory; and this science will perhaps be more successfully learned, and more deeply imprinted, by the perusal of Virgil and Horace, than by reading a thousand treatises on universal grammar. Examples seem to correspond to what is here stated. Few men have written English with force and propriety, who have been wholly

unacquainted with the learned languages. Our finest writers and speakers have been men who amused themselves during the whole of their lives with the perusal of the classics. Nothing is generally more easy than to discover by his style whether a man has been deprived of the advantages of a literary education. He who has not been accustomed to refine on words, and discriminate their shades of meaning, will think and reason after a very inaccurate and slovenly manner.

Two qualities are especially necessary to any considerable improvement of human understanding; an ardent temper, and a habit of thinking with precision and order. The study of the Latin language is particularly conducive to the production of the last of these qualities. In this respect the study of Latin and geometry might perhaps be recommended for a similar reason. In the study of language and its inflections, all is in order. Every thing is subjected to the most inflexible laws. The mind therefore which is accustomed to it, acquires habits of order, and of regarding things in a state of clearness, discrimination, and arrangement.

The discipline of mind, here described, is

of inestimable value. He who is not initiated in the practice of close investigation is constantly exposed to the danger of being deceived. His opinions have no standard, but are entirely at the mercy of his age, his country, the books he chances to read, or the company he happens to frequent. His mind is a wilderness. It may contain excellent materials, but they are of no use. He is unable to regulate his mind, and sails at the mercy of every breath of accident or caprice. Such a person is ordinarily found incapable of application or perseverance. All talent may perhaps be affirmed to consist of analysis and dissection, the turning a thing on all sides, and examining it in all its variety of views. An ordinary man sees an object just as it happens to be presented to him, and sees no more. But a man of genius takes it to pieces, inquires into its cause and effects, remarks its internal structure, and considers what would have been the result, if its members had been combined in a different way, or subjected to different influences. The man of genius gains a whole magazine of thoughts, where the ordinary man has received one idea; and his powers are multiplied in proportion to the number of ideas on which they are to be em-

ployed. Now there is perhaps nothing which contributes more eminently to this subtilizing and multiplication of mind, than an attention to the structure of language.

Let it be taken for granted that the above arguments sufficiently establish the utility of classical learning; it remains to be determined whether it be necessary that it should form a part of the education of youth. It may be alleged, that, if it be a desirable acquisition, it may with more propriety be made when a person is arrived at years of discretion; that it will then be made with less expense of labour and time, that the period of youth ought not to be burdened with so vexatious a task, and that our early years may be more advantageously spent in acquiring the knowledge of things, than of words. In answer to these objections it may be remarked, that it is not certain that, if the acquisition of the rudiments of classical learning be deferred to our riper years, it will ever be made. It will require strong inclination and considerable leisure. A few active and determined spirits will surmount the difficulty; but many who would derive great benefit from the acquisition, will certainly never arrive at it. The age of youth seems particularly adapted

to the learning of words. The judgment is then small, but the memory is retentive. In our riper years we remember passions, facts, and arguments; but it is for the most part in youth that we retain the very words in which they are conveyed. Youth easily contents itself with this employment, especially where it is not enforced with particular severity. Acquisitions which are disgustful in riper years, are often found to afford young persons no con temptible amusement. It is not perhaps true that, in teaching languages to youth, we are imposing on them an unnecessary burden. If we would produce right habits in the mind, it *must* be employed. Our early years must not be spent in lethargic indolence. An active maturity must be preceded by a busy childhood.

It has often been said that classical learning is an excellent accomplishment in men devoted to letters, but that it is ridiculous, in parents whose children are destined to more ordinary occupations, to desire to give them a superficial acquaintance with Latin, which in the sequel will infallibly fall into neglect. A conclusion opposite to this is dictated by the preceding reflections. We can never foresee the future destination and propensities of our children;

yet, no portion of classical instruction, however small, need be wholly lost. Some refinement of mind, some clearness of thinking, will almost certainly result from grammatical studies. Though the language itself should ever after be neglected, some portion of a general science has thus been acquired, which can scarcely be forgotten. Though our children should be destined to the *humblest* occupation, that does not seem to be a sufficient reason for our denying them the acquisition of *some* of the most fundamental documents of human understanding.*

The following method of teaching Latin, recommended by R. L. Edgeworth, F. R. S., appears exceedingly simple, natural, and pleasing, and furnishes useful hints for those who desire to teach themselves. "When children have by gentle degrees, and by short and clear conversations, been initiated in general grammar, and familiarized to its technical terms, the first page of tremulous Lilly will lose much of its horror. It is taken for granted, that the pupil can read and understand English, and that he has been accustomed to employ a dictionary. He may

* Godwin's Enquirer.

now proceed to translate from some easy book, a few short sentences: the first word will probably be an adverb or conjunction; either of them may be readily found in the Latin dictionary, and the young scholar will exult in having translated one word of Latin; but the next word, a substantive or verb, perhaps will elude his search. Now the grammar may be produced, and something of the various terminations of a noun may be explained. If *musam* be searched for in the dictionary, it cannot be found, but *musa* catches the eye, and with the assistance of the grammar it may be shown, that the meaning of words may be discovered by the united helps of the dictionary and grammar. After some days' patient continuation of this exercise, the use of the grammar, and of its uncouth collection of words and syllables, will be apparent to the pupil; he will perceive that the grammar is a sort of appendix to the dictionary. The grammatical formulæ may then, by gentle degrees, be committed to memory; and when once got by heart, they should be assiduously preserved in the recollection. After the preparation which we have recommended, the singular number of a declension will be learnt in a few minutes, by a child of

ordinary capacity, and after two or three days' repetition, the plural number may be added. The whole of the first declension should be well fixed in the memory before a second be attempted. During this process a few words at every lesson may be translated from Latin to English, and such nouns as are of the first declension may be compared with *musa*, and may be declined according to the same form. Tedious as this method may appear, it will in the end be found expeditious. Omitting some of the theoretic or didactic part of the grammar, which should only be read, and which may be explained with care and patience, the whole of the declensions, pronouns, conjugations, the list of prepositions, conjunctions, interjections, some adverbs, the concords, the common rules of syntax, may be comprised with sufficient repetitions in about two or three hundred lessons of ten minutes each: that is to say, ten minutes' application of the scholar in the presence of the teacher. A young boy should never be set to learn a lesson by heart when alone. Forty hours! Is this tedious? If you are afraid of losing time, begin a few months earlier; but begin when you will, forty hours is surely no great waste of time; the whole, or

even half of this short time, is not spent in the labour of getting jargon by rote; each day some slight advance is made in the knowledge of their combinations. What we insist on is, that *nothing be done to disgust the pupil:* steady perseverance, with uniform gentleness, will induce habit, and nothing should ever interrupt the regular return of the daily lesson. If absence, business, illness, or any other cause, prevent the attendance of the teacher, a substitute must be appointed; the idea of relaxation on Sunday, or a holiday, should never be permitted. In most public seminaries above one third, in some nearly one half, of the year is permitted to idleness: it is the comparison between severe labour and dissipation which renders learning hateful. Johnson is made to say, by one of his female biographers, that no child loves the person who teaches him Latin; yet the writer would not take all the doctor's fame, and all the lady's wit and riches, in exchange for the hourly, unfeigned, unremitting friendship which he enjoys with a son who had no other master than his father. So far from being laborious or troublesome, he has found it an agreeable employment to instruct his children in grammar and the learned languages. In the midst of a

variety of other occupations, half an hour every morning for many years, during the time of dressing, has been allotted to the instruction of boys of different ages in languages, and no other time has been spent in this employment."

It has been objected, that a classical education loses time in acquiring words only, when ideas ought to be acquired. This objection (though in a great measure unjust) would certainly be without any colour of reason, if a plan could be proposed for uniting both these purposes; if by a proper choice of books we could contrive to store the mind at different periods with such useful, moral ideas as are adapted to its capacity. The first branch of science which youth is capable of comprehending appears to be history. On the knowledge of facts, all moral reasoning must depend; and facts learned in youth are certainly better retained than those which are acquired at any succeeding period. Young boys are not interested in narrative (indeed there is hardly any other kind of composition which can engage them;) and I have generally found them more delighted with true history and biography, if not prolix, than with poetry or novels. The tales of love, and the minutiæ of private life,

do not arrest their attention so much as the adventures of heroes, and the vicissitudes of war. Now although learning be a business rather than an amusement, certainly the more acceptable it can be made to the pupils, the better. On these principles, therefore, I would venture to deviate a little from the common order of school books, which schoolmasters are more anxious to select for the purity of the Latin, than for any real instruction or entertainment they contain. I would not be understood to insinuate, that the acquisition of the language, in the most perfect manner, is not a primary object; but I am of opinion "that at a time when books are read only to exemplify grammatical rules, purity and elegance are not so much required, as when the scholar is more advanced." The initiatory books, I apprehend, have little influence in forming the taste; before that effect can take place it is necessary to be master of the rudiments, to read the language with ease, and to be able to consider it with something of a critical eye. It may please the vanity of a parent to be told, that his boy is reading Virgil or Ovid; and it may answer the master's own purpose, in a pecuniary view, to encourage this absurd vanity; but in the mean

time the real interest of the pupil is sacrificed. For what can be more ridiculous, than to involve a child, who is yet unacquainted with the literal meaning of words, in all the obscurities of figurative and poetic diction; and, before he has acquired any ideas on common things, to expect that he should feel and admire the highest efforts of the human imagination?

The books which I would recommend as proper to initiate children in the learned languages, should be plain prose, simple, easy to be construed, and dispensing such knowledge as is adapted to their capacities. I would lead them by just gradations from unadorned language, and plain fact, to elegance of style, elevation of thought, and more abstract sentiment. After some very easy Latin, just sufficient to show them the nature of construing, I think Eutropius the most proper book. It is an abridgement of perhaps the most important series of events which the annals of the globe can produce; it is one of the easiest books to read, and the style is clear and perspicuous. After Eutropius, the young scholar may have an excellent taste of biography in the lives of Cornelius Nepos, which, in point of difficulty, is properly the next step above Eutropius.

Justin may be read with the greatest advantage after the other two: he is not remarkable for the beauty or elegance of his style; but he collects so many useful facts in the history of mankind, and is, as I can testify from experience, so delightful a book to boys, that the advantages to be derived from the perusal of him infinitely counterbalances this objection. If the pupils cannot go through the whole of these authors, the parts which they read may be chosen so as to connect together, and afford them a general view of the progress and termination of the principal states of antiquity. Let them next read the most interesting parts of Cæsar and Sallust, and some of Cicero's orations. A good set of the ancient maps ought to be made use of while they are reading history; and thus Geography will be insensibly acquired, and more firmly implanted, than by any other process.

Until they can construe such Latin as Cæsar's Commentaries tolerably fluently, without the aid of a dictionary, and have gone at least once through a set of the common school exercises, such as Bailey's, no other language, not even Greek, should interfere with the Latin; otherwise the memory will be confused by the dif-

ferent grammars. But by the time they have finished the course of reading already specified, it is presumed they will be capable of understanding the study of Greek. Their minds also will now be matured, and sufficiently cultivated to relish the charms of poetry, of which the Æneid is the chastest and most captivating specimen. To the discretion of the master it may be left, how much of the Æneid can be read at school with advantage. Some of the moral Odes, all the unexceptionable Satires, and Epistles of Horace may follow, and a few of the Satires of Juvenal; varying occasionally the course of their studies by an oration of Tully, the Cato Major, the Lælius, or the Offices. Ovid and Terence I will venture to proscribe: the former, because he inculcates licentiousness; the latter, knavery. I know no spirit sooner caught by boys, than that little tricking disposition, that spirit of low cunning, which may be learned from some parts of this author. In the Comedies of Terence, the father is often a fantastic or an avaricious fool; the son a profligate; and the servant, who is the cream of the jest, a complete villain. The purity of his Latin, and the delicacy of his style, will not, in my estimation, compensate for the danger which

is incurred by the imitative faculties of youth. As for Ovid, there is another objection against him, for he corrupts the taste as well as the morals; some part of the Metamorphoses may, however, be read with advantage.*

Boys ought to read prose well before they meddle with the poets. The former has visibly so much the advantage of the latter, with respect to perspicuity and plainness of style, that I cannot but wonder how the latter came to take place of the former, in the common method of the schools. This looks something like teaching young children to stand upon their hands, before they know how to make use of their legs. Prose is necessary to teach them a proper Latin style; for the reading of the poets can do them no kindness in this respect, but rather much hurt, if they be not first well acquainted with prose. The style of poetry is so remote from the ordinary manner of expression, that to imitate it in prose, would be the most ridiculous thing in the world; and he would be sure to excite laughter, who should pretend to write a history in the strain of Virgil's Æneid, or Horace's Lyrics. To prevent

* Gregory's Essays.

therefore their confounding those two different styles, it will be necessary to make them read the historians well in the first place: by so doing, they will learn the genuine and proper signification of words, and use them accordingly: they will not be misled by the figurative use of words, phraseology, and forms of construction proper only for poetry; nor need they fear to imitate the language of their authors; whereas, in the reading of the poets, the case would be otherwise; there they could borrow nothing, without rendering their style very bombastic and ridiculous.*

The author of "Stemmata Latinitatis" has conferred an essential service on the public; but still there is wanting a dictionary for schools, in which elegant and proper English might be substituted for the barbarous translations now in use. Such a dictionary could not be compiled, we think, without an attention to the course of books which are most commonly used in schools. The first meanings given in the dictionary should suit the first authors which a boy reads; this may probably be a remote or metaphoric meaning: then the radical

* Clarke's Essay on Education, 1730.

word should be mentioned, and it would not cost a master any great trouble to trace the genealogy of words to the parent stock.

Cordery is a collection of such mean sentences, and uninstructive dialogue, as to be totally unfit for boys. Commenius's "Visible World Displayed" is far superior, and might, with proper alterations and better prints, become a valuable English school book. Both these works were intended for countries where the Latin language was commonly spoken, and consequently they are filled with the terms necessary for domestic life and conversation: for this very reason they are not good introductions to the classics. Selections from Bailey's Phœdrus will be proper for young beginners on account of the glossary. We prefer this mode of assisting them with glossaries to the use of translations, because they do not induce indolent habits, and yet they prevent the pupil from having unnecessary labour. Translations always give the pupil more trouble in the end, than they save in the beginning. The glossary to Bailey's Phœdrus, which we have just mentioned, needs much to be modernized, and the language requires to be improved. Mr. Valpy's Select Sentences would be far more useful if

they had a glossary annexed. As they are, they will however be useful after Phœdrus. Ovid's Metamorphoses, with all its monstrous faults, appears to be the best introduction to the Latin classics, and to heathen mythology. Norris's Ovid may be safely put into the hands of children, as it is a selection of the least exceptionable fables. Cornelius Nepos, a crabbed book, but useful from its brevity, and from its being a proper introduction to Grecian and Roman history, may be read nearly at the same time with Ovid's Metamorphoses. After Ovid the pupil may begin Virgil, postponing some of the Eclogues, and all the Georgics.*

To write exercises in Latin appears essentially necessary to grammatical perfection, and should commence as soon as the pupil has gone through the syntax. I do not feel convinced of the propriety or advantage of composing in verse. That several excellent writers had been accustomed to write Latin verses in their youth, is far from amounting to a proof in its favour, because there is great probability, that those men would have excelled, whether they had written verses at school or not. That

* Mr. R. L. Edgeworth.

to write in verse facilitates and improves our prose, I think admits of dispute. I am sure it cannot answer the end of accustoming the student to perspicuity and precision, or of perfecting him in grammar; and I apprehend it will rather serve to induce a loose and vicious mode of composition, and lead him to attend more to sound than sense. It cannot be denied, that this practice takes up much more time than a common exercise; and if it answer no particular purpose, why waste that time, which might be more usefully employed in the acquisition of ideas? The very mention of stringing words together without order or meaning, which is always the commencement, and too often the conclusion, of school versification, implies something ridiculous if not pernicious. But I will grant that a genius for poetry may receive some improvement from composing in verse when young; whether that be a desirable consequence or not, those who are parents must determine. How few poets are so happy as to succeed! and even when successful, how barren, how uncertain are the rewards of genius! The enthusiasm of poetry incapacitates us for most other employments, nor is the unsuccessful adventurer easily reduced to his sober

senses: he contends in the face of poverty, accompanied with contempt; and pursues his itch of scribbling through innumerable disappointments, without even the airy premium of applause. I have heard it urged further, in defence of these poetic exercises, that they teach boys quantity and pronunciation. But surely they never can be necessary on this account, if the master be careful from the first to accustom the learner to a right pronunciation; and were not this sufficient, the end would be fully answered by a practice, which I think as salutary as the other is pernicious; I mean that of committing to memory some of the moral passages of Virgil, Horace, and the best of the poets. This will serve at once to furnish the mind with words and with ideas; and will implant precepts in the heart, which may be useful through all the different periods of life. If it cannot impart taste, it will improve it. It will infix in the mind the best rules of grammar in indelible characters.*

It was with much regret that the compiler met with the following illiberal reflections by the enlightened and ingenious Doctor Knox

* Gregory's Essays.

"Some writers on the subject of education have expressed themselves against the general practice of composing Latin verse at schools, with a degree of acrimony, which has led their readers to conclude, that they themselves were ignorant of the art, and without a taste for its beauties. I imagine too, that some of them never had a truly classical education at a public school, or were members of either English university." Liberal Education, page 65, edit. 1783. Again, "Such objections appear very plausible to illiterate persons, and those very many who know not what a classical education means, or what advantages it tends to produce!" Page 68. In the same work, page 284, Dr. Knox acknowledges, that Mr. Locke, who wrote decidedly against boys making verses at school, was a student of Christ Church College, Oxford; and wrote there some Latin verses addressed to Cromwell. But he also remarks, that "Locke was led to differ from others on the subject of education from a warmth of reforming spirit." Those assertions do not appear well founded, for Locke produced his "Thoughts on Education" at the age of fifty-eight. It might therefore be said with greater plausibility, that his decisions on this subject,

were the result of much experience, mature judgment, and cool discrimination.

The assertion will not perhaps be liable to be controverted by those, who are best acquainted with such subjects, and are best qualified to make extensive and just comparisons, if it be said that the Greek claims the superiority over all other languages. In its numerous modes of expression there is precision without obscurity, and copiousness without redundance. It owes the former to the various and diversified inflections of its words, and the latter to its great number of derivatives. In its general structure and formation, a proper regard is paid to the ear, as well as to the understanding; for its energy and strength are not more striking than its harmony. The strictness of its rules does not impose too much restraint upon its expressions, and its grammatical system is in every part exact and complete.*

From a short view of its history and characteristics, it will be evident, that this language deserves to be held up as a perfect model of expression, and that it fully justifies the praise of those scholars and critics, who have cele-

* See Lord Monboddo on the Origin of Language, vol. iv. page 25.

brated its excellence in proportion as they have enjoyed its beauties, and derived taste, improvement, and pleasure, from the perusal of its incomparable writers.*

Greek is worth the pains of learning, merely as a language; and I question whether any man can be an adequate judge of the structure, force, and harmony of language, who is totally ignorant of it. The true principles of taste are to be imbibed in their greatest perfection from the Greek writers, whose chastity, perspicuity, and elegance, have never been excelled, and very seldom equalled. In teaching Greek, the most proper book to commence with is certainly one of the Gospels. I would prefer St. Matthew's, because I think it written in a more agreeable and entertaining manner than that of St. John, which is usually the first book. Of the New Testament, Matthew and Luke will be quite sufficient. After these I would recommend some easy prose; perhaps the Pictures of Cebes would not be found too difficult. A few of the Odes of Anacreon, if selected with judgment, may be read. My predilection for History inclines me to recommend as much of Herodotus as may

* Mr. Kett's Elements of General Knowledge.

conveniently be read. It is the most entertaining book I am acquainted with; and much solid instruction may, on the whole, be collected from it. The style is simple and beautiful, with this additional circumstance in its favour, that it is the best introduction to Homer. Some schoolmasters may prefer the Cyropædia of Xenophon, which is an excellent book, if the boys do not think it prolix. It is almost needless to mention, that the Anabasis is the best of all that author's works. After as much of Homer as may be thought expedient, it may be of use to dip a little into the Orations of Isocrates, as introductory to Demosthenes, who must by no means be neglected. Of the Manual of Epictetus the master may, if he pleases, make considerable advantage, by taking occasion to explain from it the moral philosophy of the Stoics. Thucydides, as well as Livy and Tacitus, the higher poets and philosophers, must, I fear, be reserved for the university; as no school class can be expected to go through a greater number of books than those which I have already specified. By pursuing this plan of reading, I am persuaded the student would reap much more useful knowledge, than by the jumbled, unsystematic method commonly pur-

sued in schools. What, perhaps, he would be most deficient in, would be the heathen mythology, of the great advantage of which I must confess myself ignorant. In return, he would be master of all the leading facts in the history of mankind; and if history be to ethics what experiment is to physics, he would have laid the best foundation of moral reasoning. None of the advantages of classical learning, in respect to the improvement of taste, would be lost by this course of study; and perhaps the style which would be formed from the authors I have recommended, would be preferable to the prettinesses which is acquired from reading poetry; being formed on the best models of that manly eloquence, which is the proper associate and embellishment of virtuous principles. I have omitted entering into a detail of the manner in which I would have the rudiments taught, because I do not in this respect, materially differ from the common practice of schools. Before a boy be put to construe, he should be well grounded in the Accidence, perfectly master of the declensions of nouns and verbs, as well as the rules for determining the genders, and the formation of the tenses. But I do not think there is an absolute necessity,

previous to the reading of any author, to overcharge his memory with a multitude of syntax rules, of the use and application of which he must be totally ignorant. The concords, and a few of the principal rules, will be quite enough for him when he begins to construe. He must afterwards continue to get off a portion of the other rules every day, and must be well exercised in the grammar during the whole of his progress.

I agree with Mr. Knox, that to teach wholly by translations is pernicious. But I must observe, that if with the first and second books which a child is put to construe, no translation be made use of, the master himself must be in place of a translation; or the pupil must, at the expense of some of his pocket money, apply to his school-fellows. It is impossible, on the first efforts to construe, to proceed without some guide; or to use a dictionary with that ease and dexterity which are essential to profit. To allow them the assistance of a translation at first, and before they have acquired a little stock of words, is more suitable to the progressive powers of the human mind. I grant there will be some difficulty to be surmounted when they first lay aside the translation; but this will be

nothing like so discouraging as the gloomy prospect of entering on a language totally unknown, and being obliged to consult a dictionary for every word.*

The modern practice of teaching Greek through the medium of Latin appears to me highly erroneous. It not only retards the progress of a scholar, but it renders the idioms of both languages confused; and the beauty of the article, and some of the tenses, independent of other considerations, is thus entirely lost. The labours of literary men cannot be directed to a more useful purpose, than the compilation of dictionaries and grammars in the Greek and vernacular tongues.†

To the objection that too much time is lost in learning the *words* of the sentiments which we might obtain by means of translations, this plain answer may be given, that a person can never learn a language, without adding to the stock of his ideas; and that the better the language is, (and where shall we find any equal to the Greek and Latin?) the more correct will be the judgment, and the more vigorous the perceptions of the learner. The learned tongues

* Gregory's Essays. † Northmore.

form at once, even considered merely in their structure, the best code of laws for taste, and the best models for logical reasoning and argument. No one who can read the classics would exchange the fruit of the time spent upon them for any other attainment which his earlier years could have made.*

The Earl of Chatham says to his nephew, "I rejoice to hear that you have begun Homer's Iliad; and have made great progress in Virgil; I hope you taste and love these authors particularly. You cannot read them too much, they are not only the two greatest poets, but they contain the finest lessons for your age to imbibe: lessons of honour, courage, disinterestedness, love of truth, command of temper, gentleness of behaviour, humanity, and in one word, virtue, in its true signification. Go on, my dear nephew, and drink as deep as you can of these divine springs: the pleasure of the draught is equal at least to the prodigious advantages of it to the heart and morals.†

There is yet wanting in different languages, says Stevenson, initiatory books, containing

* Edinburgh Review, iii. 351.

† Letters to T. Pitt, Esq., afterwards Lord Camelford, page 6.

physical facts, none of which would be dry and uninteresting. Natural History and Philosophy, in all their branches, even though they were superficial, would be of much greater use in every situation in life, than an intimacy with poetic flights of imagination, and all the lumber of the heathen mythology, the perusal of which affords but selfish, momentary, and insulated pleasure. Young people remember facts much more readily than sublime metaphor, or laboured sentiment.*

Though I particularly recommend classical learning, says Dr. Knox, I do not recommend it exclusively. I think it ought to claim the earliest attention, and to form the foundation; because no other learning contributes so much to open and to polish the mind. After this polish and expansion are acquired, and this foundation laid, I recommend an attention to the sciences, to natural history and experimental philosophy, to botany, to chemistry, to painting, to architecture, to mechanical works, and in general to all the productions of human ingenuity. A capacious mind will view the universe and all which it contains, as one vast

* Remarks on the inferior utility of Classical Learning

volume laid before it for perusal. Philology alone is comparatively a confined, though elegant attainment.

MATHEMATICS.

Arithmetic may now be considered as having advanced to a degree of perfection which in former times could scarcely have been conceived, and to be one of those few sciences which have left little room for farther improvement. It is, however, a serious and almost general complaint, that few children, while at school, make any tolerable progress in arithmetic; and that the generality, after having spent several years under the tuition of a master, are incapable of applying the few rules which they have learned, to the useful purposes of life. A few elementary principles are acquired by rote, and therefore quickly forgotten; because the most essential particulars, namely, the reasons on which these rules are founded, and their extensive use in the various concerns of society are generally omitted.*

So much of the science of numbers as is in common use, as the numeration, subtraction,

* Dom. Encyclopædia.

multiplication, and division of money, should be learnt with accuracy; to which should be added the rule of three and decimal fractions; which will abundantly repay the labour of acquiring them by the pleasure and utility which will perpetually result from the knowledge of them through life.*

The only sciences which can be denominated pure are the Mathematics. Of these, every mechanic and labourer should be made acquainted with Euclid, particularly the first six books; also algebra; the properties of the conic sections; and the doctrine of fluxions. Owing to the very little attention which is paid to these sciences at present, it may appear to many, that their study is attended with great difficulty, and little advantage. Neither of these prejudices borders on the confines of truth. In order that those sciences may become capable of gratifying the desire which children entertain for the acquisition of truth and knowledge, it is absolutely necessary that they be rendered as clear and evident as possible, and also that their application and utility be made apparent. Nothing more seems wanting to render the study of mathematics pleasant and agreeable,

* Dr. Darwin.

than to apply them to those purposes which must make their utility and perfection clear striking, and interesting. The time in which mathematics should be studied, must succeed that of literature. To comprehend abstract and general truth, some energy and comprehension of mind are requisite. To point out the precise period when the study of mathematical science should commence, is attended with some difficulty. It must evidently vary, according to the progress which the mind may have made towards maturity and perfection.*

I agree with Mr. Locke, that there is no study better fitted to exercise and strengthen the reasoning powers, than that of the mathematical sciences, for two reasons; first, because there is no other branch of science which gives such scope to long and accurate trains of reasoning; and, secondly, because in mathematics there is no room for authority, nor for prejudice of any kind, which may give a false bias to the judgment. When a youth of moderate parts begins to study Euclid, every thing at first is new to him. His apprehension is unsteady; his judgment is feeble, and rests partly upon the evidence of the thing, and partly upon the authority

* Dr. Cowan.

of his teacher. But every time he goes over the definitions, the axioms, the elementary propositions, more light breaks in upon him: the language becomes familiar, and conveys clear and steady conceptions; the judgment is confirmed; he begins to see what demonstration is; and it is impossible to see it without being charmed with it. He perceives it to be a kind of evidence which has no need of authority to strengthen it. He finds himself emancipated from that bondage; and exults so much in this new state of independence, that he spurns at authority, and would have demonstration for every thing; until experience teaches him, that this is a kind of evidence which cannot be had in most things; and that in his most important concerns, he must rest contented with probability. As he goes on in mathematics, the road of demonstration becomes smooth and easy; he can walk in it firmly, and take wider steps: and at last he acquires the habit, not only of understanding a demonstration, but of discovering and demonstrating mathematical truths. Thus, a man, without rules of logic, may acquire a habit of reasoning justly in mathematics; and, I believe he may, by like means, acquire a nabit of reasoning justly in mechanics,

in jurisprudence, in politics, or in any other science.

LOGIC.

Good sense, good examples and assiduous exercise, may bring a man to reason justly and acutely in his own profession, without rules. But if any man think, that from this concession he may infer the inutility of logic, he betrays a great want of that art by this inference: for it is no better reasoning than this, that because a man may go from Edinburgh to London by the way of Paris, therefore any other road is useless. There is perhaps no mechanic art which may not be acquired, in a very considerable degree, by example and practice, without reducing it to rules. But practice, joined with rules, may carry a man on in his art farther and more quickly, than practice without rules. Every ingenious artist knows the utility of having his art reduced to rules, and by that means made a science. He is thereby enlightened in his practice, and works with more assurance. By rules, he sometimes corrects his own errors, and often detects the errors of others: he finds them of great use to confirm his judgment, to justify what is right, and to condemn what is wrong.

Is it of no use in reasoning, to be well acquainted with the various powers of the human understanding, by which we reason? Is it of no use, to resolve the various kinds of reasoning into their simple elements; and to discover, as far as we are able, the rules by which these elements are combined in judging and in reasoning? Is it of no use, to mark the various fallacies in reasoning, by which even the most ingenious men have been led into error? It must surely betray great want of understanding, to think these things useless or unimportant. These are the things which logicians have attempted, and which they have executed; not indeed so completely as to leave no room for improvement, but in such a manner as to give very considerable aid to our reasoning powers. That the principles laid down with regard to definition and division, with regard to the conversion and opposition of propositions and the general rules of reasoning, are not without use, is sufficiently apparent from the blunders committed by those who disdain any acquaintance with them.*

Geometry should always form a part of a

* Lord Kaimes' Sketches.

liberal course of studies. It has its direct uses and its indirect. It is of great importance for the improvement of mechanics and the arts of life. It is essential to the just mastery of astronomy and various other eminent sciences But its indirect uses are perhaps of more worth than its direct. It cultivates the powers of the mind, and generates the most excellent habits. It eminently conduces to the making man a rational being, accustoms him to a closeness of deduction, which is not easily made the dupe of ambiguity, and carries on an eternal war against prejudice and imposition.* But geometry is not a competent guide to the art of reasoning without the study of logic.

It is a very great error to suppose that logic consists only in those formal debates and verbal disputations, in which the schoolmen and their followers consumed so much time in the dark ages, previous to the revival of classical learning. It is equally a mistake to imagine, that it is merely intended to teach the method of disputing by rules, and to instruct a person to converse, not from a love of truth, but a desire of victory. As there is nothing more

* Godwin's Enquirer.

disingenuous than such a conduct as this, nothing more unbecoming a rationable being, than to oppose sophistry to good sense, and evasion to sound argument, the logician disclaims this abuse of the principles of his art, and vindicates its rights by displaying its true and proper office. It is in reality capable of affording the most important assistance to the understanding in its inquiries after truth; it is eminently useful in the common affairs of life, and renders the greatest service to science, learning, virtue, and religion.

Logic is the art of forming correct ideas, and of deducing right inferences from them; or it may be said to constitute the knowledge of the human mind, inasmuch as it traces the progress of all our information, from our first and most simple conception of things, to those numerous conclusions which result from comparing them together. It teaches us in what order our thoughts succeed each other, and it instructs us in the relation which subsists between our ideas, and the terms in which we express them It distinguishes their different kinds, and points out their properties; discovers the sources of our intellectual mistakes, and shows how we may correct and prevent them. It displays

those principles and rules, which we follow, although imperceptibly, whenever we think in a manner conformable to truth.

The faculty of reason is the pre-eminent quality, by which mankind are distinguished from all other animals; but still we are far from finding that they possess it in the same degree. There is indeed as great an inequality in this respect in different persons, as there is in their strength and agility of body. Nor ought this disproportion to be wholly ascribed to the original constitution of the minds of men, or the difference of their natural endowments; for, if we take a survey of the nations of the world, we shall find that some are immersed in ignorance and barbarity, others enlightened by learning and science; and, what is still more remarkable, the people of the same nation have been in various ages distinguished by these very opposite characters. It is, therefore, by due cultivation, and proper diligence, that we increase the vigour of our minds, and carry reason to perfection. Where this method is followed, the intellect acquires strength, and knowledge is enlarged in every direction; where it is neglected, we remain ignorant of the value of our own powers; and those faculties, by

which we are qualified to survey the vast fabric of the world, to contemplate the whole face of nature, to investigate the causes of things and to arrive at the most important conclusions as to our welfare and happiness, remain buried in darkness and obscurity. No branch of science therefore affords us a fairer prospect of improvement, than that which relates to the understanding, defines its powers, and shows the method by which it acquires the stock of its ideas, and accumulates general knowledge.*

COMPOSITION.

When we are employed after a proper manner, in the study of composition, we are cultivating reason itself. True rhetoric and sound logic are very nearly allied. The study of arranging and expressing our thoughts with propriety, teaches us to think, as well as to speak, accurately. By putting our sentiments into words we always conceive them more distinctly. Every one who has the slightest acquaintance with composition knows, that when he expresses himself ill on any subject, when his arrangement is loose, and his sentences become

* Mr. Kett's Elements.

feeble, the defects of his style can, almost on every occasion, be traced back to his indistinct conception of the subject: so close is the connection between thoughts and the words in which they are clothed. The study of composition, important in itself at all times, has acquired additional importance from the taste and manners of the present age; an age wherein improvements, in every part of science, have been prosecuted with ardour. To all the liberal arts much attention has been paid; and to none more than to the beauty of language, and the grace and elegance of every kind of writing. The public ear is become refined. It will not easily bear what is slovenly and incorrect. Every one who writes must aspire to some merit in expression, as well as in sentiment, if he would not incur the danger of being neglected and despised. I will not deny that the love of minute elegance, and attention to inferior ornaments of composition, may have engrossed too great a degree of the public regard. It is indeed my opinion, that we lean to this extreme; often more careful of polished style, than of storing it with thought. Yet hence arises a new reason for the study of just and proper composition. If it be requisite not to be defi-

cient in elegance and ornament, in times when they are in such high estimation, it is still more requisite to attain the power of distinguishing false ornament from true, in order to prevent our being carried away by that torrent of false and frivolous taste, which never fails, when it is prevalent, to sweep along with it the raw and the ignorant. They who have never studied eloquence in its principles, nor have been trained to attend to the genuine and manly beauties of good writing, are always ready to be caught by the mere glare of language; and when they come to speak in public, or to compose, have no other standard on which to form themselves, except what chances to be fashionable and popular, how corrupted soever and erroneous that may be.*

Though I have advised the pupil to exercise himself in composition, yet I will also caution him against the itch of scribbling. Let him never take the pen in hand, nor place the paper before him, till he has bestowed much time and deep thought on the subject. To the want of this previous attention we owe the numerous productions which disgrace letters, and which die almost as soon as they are brought forth;

* Dr. Blair's Lectures.

which, like weeds in a garden, spring up luxuriantly without cultivation, which are useless or noisome, and which only serve to impede the growth of salutary plants and pleasant flowers. Pretenders arise in every department, and disgrace it. Let the liberal and solid scholar attend to the circumstances of time and place, in the modest display of his attainments. It is unmanly timidity to conceal them on proper occasions; it is ridiculous arrogance to intrude on unwilling and injudicious observers. Modesty is the characteristic of real merit; and firmness, of conscious dignity. The man of sense will be diffident, but at the same time will have spirit enough to repel the insolent attacks of ignorance and envy.*

IMPROVEMENT OF THE MEMORY.

The following observations, if attended to, may greatly assist those more advanced in life, in strengthening the memory. 1. Let the student never quit any branch of study till he be perfectly master of it, and can comprehend it as a whole, as well as in parts. 2. Endeavour to link and connect the leading ideas, to class facts, and arrange them under different heads;

* Dr Knox.

so that the mind shall be able at one view to recall the outlines of the whole science, and afterwards to pass to the inferior branches, or subdivisions. The ancients formed their memories almost entirely by this method; and indeed memory can never be useful without system. 3. Never commit mere words to memory as substitutes for true knowledge. Many a young person forgets what he has been taught because he never understood it. This is the true reason why boys make so wretched a proficiency in attaining the Latin language, under masters who give them page after page of old Lilly to commit to memory, without the occurrence of a question or an explanation. In this manner they are also taught their catechisms, the ideas in which are infinitely above their comprehension.

The first thing which strikes us, in looking over Dr. Franklin's works, is the variety of his observations on different subjects. We might imagine, that a very tenacious and powerful memory was necessary to register them; but Dr. Franklin informs us, that it was his constant practice to note down every thing as it occurred to him: he urges his friends to do the same; he observes, that there is scarcely a day

passes without our hearing or seeing something, which, if properly attended to, might lead to useful discoveries. By thus committing his ideas to writing, his mind was left at liberty to think. No extraordinary effort of memory was, even on the greatest occasions, requisite.*

On the whole, the most effectual way to acquire a good memory is by constant and moderate exercises of it; for the memory, like other habits, is strengthened and improved by daily use. It is scarcely credible to what a degree both active and passive memory may be improved by long practice. Scaliger reports of himself that in his youth he could repeat above one hundred verses, having but once read them; and Boëthius declares, that he wrote his comment on Claudian without consulting the text. The extraordinary memory of Magliabechi is well known. That of Jediah Buxton was of a peculiar kind; so long was it habituated to numbers, that it could fix on nothing else. To hope, however, for such degrees of memory as these, would be equally vain as to hope for the strength of Hercules, or the swiftness of Achilles. There are clergy-

* Chiefly by Miss Edgeworth.

men who can get a sermon by heart in two hours, though their memory when they began to exercise it, was rather weak than strong: and pleaders, with other orators, who can speak in public extempore, often discover, in calling instantly to mind all the knowledge necessary on the present occasion, and every thing of importance which may have been advanced in the course of a long debate, such powers of retention and recollection as, to the man who has never been obliged to exert himself in the same manner, are altogether astonishing. As habits, in order to be strong, must be formed in early life, the memories of children should therefore be constantly exercised; but to oblige them to commit to memory what they do not understand, prevents their faculties, and gives them a dislike to learning. In a word, those who have most occasion for memory, as orators and public speakers, should not suffer it to lie idle, but constantly employ it in treasuring up and frequently reviving such things as may be of most importance to them; for by these means, it will be more at their command, and they may place greater confidence in it on any emergency.*

* The Idler.

CHAPTER XI.

THE MECHANIC'S STUDIES CONTINUED.

Natural Philosophy is commonly defined to be that art or science which considers the powers and properties of natural bodies, and their mutual action on each other. Moral Philosophy relates to whatever concerns the mind and intellect; Natural Philosophy, on the other hand, is only concerned with the material part of the creation. The moralist's business is to inquire into the nature of virtue, the causes and effects of vice, to propose remedies for it, and to point out the mode of attaining happiness. The naturalist, on the contrary, has nothing to do with spirit; his business is confined to body or matter. The first and principal part of this science is to collect all the manifest and sensible appearances of things, and reduce them into a body of Natural History.

Natural Philosophy differs from Natural History in its appropriated sense, the business of the latter is only to observe the appearance of natural bodies separately, and from these

appearances to class them with other bodies to which they are allied. Natural Philosophy goes farther, and recites the action of two or more bodies upon each other; and though it can neither investigate nor point out the causes of those effects, whatever they be, yet from mathematical reasoning combined with experience, it can be demonstrated, that in such circumstances such effects must always take place

Natural Philosophy, till lately, has been divided into four parts, commonly called the foui branches, viz.—1. Mechanics; 2. Hydrostatics; 3. Optics; and 4. Astronomy; and these again subdivided into many parts. Modern discoveries have added, however, two more parts, viz., 1. Magnetism; 2. Electricity and Galvanism. Every one is acquainted with the benefits derived from the sciences of Mechanics, Hydrostatics, and Hydraulics, to which we are indebted for many useful inventions. Among these are wind and water mills, aqueducts, pumps, fire engines, steam engines, &c., &c.

Pneumatics supply, even to a superficial enquirer, much instruction and amusement. Surely all are interested in the nature and properties of a fluid which is necessary to every moment of our existence.

How great would have been the surprise of the ancients, could they have conceived the effects which are now produced by the reflection and refraction of light! By a skilful management of these properties, telescopes, and various optical instruments are constructed. Objects too remote to be perceived by the naked eye, are enlarged and rendered visible. The satellites of Jupiter and Saturn, the mountains and cavities in the moon, and the changes which take place on the sun's disc, are thus discovered, and afford subject for admiration and inquiry. Neither is the delightful scene of Optics confined to the contemplation of distant objects. Minute animals, the vessels of plants, and, in short, a new world in miniature is disclosed to our view by the microscope, and an inexhaustible fund of rational entertainment and knowledge is brought within the spere of our senses.

Of all the sciences to which geometry imparts the solidity of its principles, and the clearness of its proofs, the most beautiful and the most sublime is Astronomy. This is perhaps the most exact and most definite part of natural philosophy: for it rectifies the errors of sight, with respect to the apparent motions of the planets; explains the just dimensions.

relative distances, due order, and exact proportions of the spherical bodies, which compose the solar system. Nor is it even confined to these great objects of nature, since it opens the stupendous prospect of other suns, and other systems of planets, scattered over the boundless fields of space, and moving in obedience to their respective laws. It marks out their particular places, assigns their various names, and classes all the systems of worlds in their respective constellations. The calculations of astronomy prove the certainty of the future phenomena of the heavenly bodies, when the eccentric comet will reappear, after having traversed the most distant regions of the heavens, or at what point of time the bright luminaries of day and night will be immersed in the partial, or total darkness of an eclipse.

CHEMISTRY.

As soon as man begins to think, and to reason, the different objects which surround him on all sides naturally engage his attention. After being astonished at the wonders of the atmospheric and higher regions, he cannot fail to be struck with the number, diversity, and beauty of those on earth, and naturally feels a

desire to be better acquainted with their properties and uses. If he reflect also, that he himself is altogether dependent on these objects, not merely for his pleasures and comforts, but for his very existence, this desire must become irresistible. Hence that curiosity, that eager thirst for knowledge, which animates and distinguishes generous minds.

As a science, chemistry is intimately connected with all the phenomena of nature; the causes of rain, snow, hail, dew, wind, earthquakes; even the changes of the seasons can never be explored with any chance of success while we are ignorant of chemistry: and the vegetation of plants, and some of the most important functions of animals, have received all their illustration from the same source. No study can give us more exalted ideas of the wisdom and goodness of the eternal cause than this. As an art, it is intimately connected with all our manufactures: the glass-blower, the potter, the smith, and every other worker in metals; the tanner, the soap-maker, the dyer, the bleacher, are practical chemists; and the most essential improvements have been introduced into all these arts by the progress which chemistry has made as a science. Agriculture

can only be improved rationally, and certainly, by calling in the assistance of chemistry; and the advantages which medicine has derived from the same source, are too obvious to be pointed out.*

NATURAL HISTORY.

I am convinced, says Rousseau, that at all times of life, the study of nature abates the taste for frivolous amusements, prevents the tumult of the passions, and provides the mind with a nourishment which is salutary, by filling it with objects most worthy of its contemplation.

Of all the studies in which the minds of youth may be employed, none, perhaps, deserve more strongly to be recommended, than those of natural history and physics. The objects on which they are occupied being such as come under the cognizance of our senses, they are more easily comprehended by the juvenile understanding, than the refinements of grammar or the abstract ideas of moral philosophy: at the same time, they afford an inexhaustible fund of entertainment; and their great utility in

* Thomson's Chemistry.

every situation in life is universally acknowledged.*

It is the glorious privilege of man, while other animals are confined within the limits which instinct has prescribed, to carry his observations beyond his own immediate wants, and to contemplate the universe at large. He extends his inquiries to all the objects which surround him; exercises his judgment, and informs his understanding, by ascertaining their nature, properties, and uses. In the various branches of mathematics, in the abstract speculations of metaphysics, or in searching the records of history, he is solely intent on the operations of his own mind, or the actions of himself and his fellow creatures: but in the study of nature, he examines every object presented to his senses, and takes a general survey of the wide and interesting prospect of the creation. The earth he treads, the ocean he crosses, the air he breathes, the starry heavens on which he gazes, the mines and caverns he explores, all present to him abundant materials for his researches. And, when thus employed, he is engaged in a manner peculiarly suitable to his

* Preface to Pleasing Preceptor.

faculties, since he alone is capable of knowledge, he alone is distinguished by the power of admiration, and exalted by the faculty of reason. The terraqueous globe presents a most glorious and most sublime prospect, equally worthy of the capacity of man to contemplate, and beautiful to his eye to behold. And the treasures of nature, which this prospect comprehends, are so rich and inexhaustible, that they may furnish employment for his greatest diligence, stimulated by the most ardent curiosity and assisted by the most favourable opportunities. At the same time that she solicits him to follow her, not only in her open walks, but likewise to explore her secret recesses, she fails not to reward him with the purest gratifications of the mind, because at every step he takes, new instances of beauty, variety, and perfection are unfolded to his view.

The study of the works of nature is in itself capable of affording the most refined pleasure, and the most edifying instruction. All the objects with which we are surrounded, the smallest as well as the greatest, teach us some useful lesson. All of them speak a language directed to man, and to man alone. Their evident tendency to some determined end, marks the de-

sign of a great Creator. The volume of creation contains the objects of arts, science, and philosophy, and is open to the inspection of all the inhabitants of the globe. Nature speaks by her works an universal language, the rudiments of which are peculiarly adapted to the inclination and capacity of the young, whose curiosity may be gratified and excited by turns; but more profound and extensive inquiries are suitable to the contemplation of persons of every age; and no subjects can be more worthy of their attentive observation.*

A walk in the fields, after reading a little in natural history, may furnish opportunities of important instruction. The hills, the dales, and quarries afford matter of speculation on their formation, use, and beauty. And this may be rendered intelligible to a child, by a person who really understands the subject, and is not a mere pedant who has only committed technical words to memory. So in all probability may every branch of real knowledge. Those branches which are now lost to common sense by calculations and mathematical processes, are not always, if they be ever understood by those

* Mr. Kett's Elements.

who profess to understand them. Every thing which is not applicable to use, and the application of which cannot be made obvious to common sense, is gothic jargon, and not science; and people who glory in such acquisitions have not a clear and good idea of what constitutes real knowledge. This explains the problem, why, in the present state of learning, there are no plain, intelligible, and easy methods of teaching the sciences, and so few good elementary books. The reason is, that the sciences are not generally and thoroughly understood. Every man can easily teach another what he perfectly understands himself. But if half his terms be merely technical, and he can give no definitions of them which convey ideas, it is no wonder that learning is difficult, as it is always painful to commit to memory words which have no meaning; and all the progress made upon such foundations is ever attended with that anxiety and anguish, which have so strongly marked the countenances of our philosophers. In the same manner as the general truths of natural history might be occasionally exemplified in the fields, many of the mathematic, astronomic, and particularly the mechanic problems, might be examined in a walk. This would not only

be present instruction, but bring the pupil into a habit of having an object and a view in every action. He would not then experience the common unhappiness of not knowing what to do with himself; or when he has determined on a walk or a ride, be miserable for want of being able to determine where to go, or with what object to engage his thoughts.*

CHAPTER XII.

THE MECHANIC'S STUDIES CONTINUED

HISTORY.

Curiosity is one of the strongest and most active principles of human nature. Throughout the successive stages of life, it seeks with avidity for those gratifications, which are congenial with the different faculties of the mind. The child, as soon as the imagination begins to open, eagerly listens to the tales of his nurse: the youth, at a time of life, when the love of what is new and uncommon is quickened by sensibility, is enchanted by the magic of romances and novels: the man, whose mature judgment inclines him to the pursuit of truth, applies to genuine history, which even in old age continues to be a favourite object of his attention; since his desire to be acquainted with the transactions of others has nearly an equal power over his mind with the propensity to relate what has happened to himself

History, considered with respect to the nature of its subjects, may be divided into general and

particular; and with respect to time, into ancient and modern. Ancient history commences with the creation, and extends to the reign of Charlemagne, in the year of our Lord 800. Modern history, beginning with that period, reaches down to the present times. General history relates to nations and public affairs, and may be subdivided into sacred, ecclesiastical, and profane. Biography, memoirs, and letters, constitute particular history. Statistics refer to the present condition of nations. Geography and Chronology are important aids, and give order, regularity and clearness to them all.

To draw the line of proper distinction between authentic and fabulous history, is the first object of the discerning reader. Let him not burden his memory with events which ought perhaps to pass for fables; let him not fatigue his attention with the progress of empires, or the succession of kings, which are thrown back into the remotest ages. He will find that little dependence is to be placed upon the relations of those affairs in the Pagan world, which precede the invention of letters, and were built upon mere oral tradition. Let him leave the dynasties of the Egyptian kings, the expeditions of Sesostris, Bacchus, and Jason,

and the exploits of Hercules and Theseus, for poets to embellish, or chronologists to arrange. The fabulous accounts of these heroes of antiquity may remind him of the sandy deserts, lofty mountains, and frozen oceans, which are laid down in the maps of the ancient geographers, to conceal their ignorance of remote countries. Let him hasten to firm ground, where he may safely stand, and behold the striking events, and memorable actions, which the light of authentic records display to his view. They alone are amply sufficient to enrich his memory, and to point out to him well attested examples of all that is magnanimous, as well as of all that is vile; of all that debases, and all that ennobles mankind.*

Unfortunately the study of history is not without its dangers and inconveniences of various kinds. It is a very difficult matter to place one's self in such a point of view as to be able to judge equitably of our fellow creatures. It is one of the common vices of history to paint man in a disadvantageous rather than in a favourable light. Revolutions and fatal catastrophes being most interesting, so long as a people have continued to increase and

* Mr. Kett's Elements.

prosper in the calm of a peaceab.e government, history has remained silent; it speaks of nations only when, growing insupportable to themselves, they begin to interfere with their neighbours, or to suffer their neighbours to interfere with them. We are favoured with very exact accounts of those nations which verge towards destruction; but of those which have been flourishing, we have no history; they have been so wise and happy as to furnish no events worth recording. The historical relations of facts which we meet with, are by no means accurate delineations; they change their aspect in the brain of the historian, they bend to his interest, and are tinctured by his prejudices. What historian ever brought his reader to the scene of action, and laid the event cir cumstantially as it happened? Ignorance and partiality disguise every thing. How easy it is to give a thousand varied appearances to the same facts, merely by a difference in the representation of circumstances. Exhibit an object in different points of view, and we scarcely believe it to be the same, and yet nothing is changed, except the eye of the spectator. How often has it happened that a few trees, a hill on the right or left, or a sudden cloud of dust,

have turned the scale of victory, without the cause first being perceived? Nevertheless the historian will assign a reason for the victory or defeat with as much confidence as if he had been at the same instant in every part of the battle. The worst historians, for a young reader, are those who favour us with their judgment. A plain narrative of facts is all he wants: let him judge for himself, and he will learn to know mankind. If he be constantly guided by an author's opinion, he sees only with the eyes of another; and when these are taken from him he does not see at all. History is generally defective in recording only those facts which are rendered conspicuous by name, place, or date; but the slow progressive causes of those facts, not being thus distinguished, remain for ever unknown. A madness for party having possession of them all, they never endeavour to see things as they really are, but as they best agree with their favourite hypotheses.*

It is the business of history to distinguish between the miraculous and marvellous; to reject the first in all narrations merely profane and human; to scruple the second; and when

* Rousseau, b. iv.

obliged by undoubted testimony to admit of something extraordinary, to receive as little of it as is consistent with the known facts and circumstances.*

In undertaking a course of history, it is certainly of great advantage to follow the chronological order of events. You have then the gradual progress of man from barbarism to refinement; from refinement to corruption, venality, and slavery; from slavery back again to darkness and ignorance; and from this state again to knowledge, civilization, and liberty. The most ancient history, except the Bible, is Herodotus; and no history was ever more delightful for its simplicity, perspicuity, the unaffected style of the narrative, and easy and harmonious flow of the language. Mr. Beloe's translation, though not elegant, partakes in some measure, of the simplicity of the original. The history of Thucydides takes not so wide a scope as that of Herodotus, but the period which he describes is interesting, and his manner is incomparable. Smith's translation is tolerably good, and even that of Hobbes may be read without disgust. A more connected

* Hume.

view of ancient history may be learnt from Rollin. The Ancient Universal History is an excellent and elaborate compilation, but it is tedious, and the style is dry and inharmonious: it is a book therefore rather for reference than study. The indefatigable Dr. Mavor has produced an abridgment of this work, with additions, to the year 1802, in 25 volumes, 18mo Of the Roman historians there is a deplorable dearth of good translations. The order in which they may be read is Livy, Sallust, Cæsar. The Epistles of Cicero are chiefly historical, which are admirably translated by Mr. Melmoth. Plutarch's Lives should be read immediately after the Greek and Latin historians, or rather in conjunction with them: a good translation has been done by the brothers Langhorne. Of modern works, Vertot's Roman Revolutions, Montesquieu's Greatness and Decline of the Romans, and Dr. Middleton's incomparable Life of Cicero, may be read with the ancient historians. The last is a production of original genius, and yet comprises all which is most excellent in the writings of the great man whose life it narrates. The Anabasis of Xenophon, and the history of Polybius are most interesting and engaging books; of the

latter there is a translation by Hampton. Of the English compilations which contain the history of the Roman commonwealth, Ferguson's is preferable to Hook's. Suetonius's History of the Twelve Cæsars is an ill-written book, yet it contains facts which are not to be found in any other original author. Tacitus is a treasure, not merely on account of the historical matter which it contains, but for the mass of moral instruction which it conveys. Murphy's translation may be pronounced superior to Gordon's. After finishing Tacitus, we must, of necessity, have recourse to compilation. Mr. Gibbon takes up the subject where Tacitus left it, and certainly a nobler monument of genius was never erected, than the "Decline and Fall of the Roman Empire;" a narrative which extends to so modern a period, that a few books will serve to unite the chain of history with that of our own country. Dr. Robertson's Charles the Fifth is perhaps the most perfect historical composition in the English language; and Dr. Watson's history is well connected with it; both of which relate to some of the most important events recorded in history, the reformation of religion, and the establishment of the Batavian republic. Mr.

Wraxall has filled up a chasm on the historical shelf, by his agreeable history of France; yet the student should not satisfy himself with that author's account of the age of Henry the Great, but inspect for himself the interesting and unblemished pages of Sully; and there are few scholars who will not find exquisite pleasure in the general history of the correct De Thou. Vertot's Revolutions of Sweden and of Portugal, are both of them animated narratives of important events. Voltaire's Age of Louis the fourteenth and fifteenth, may be classed among original histories, though not of the first rank; his Charles the Twelfth borders much on the romance. Dr. Robertson's History of America is a much admired composition. After such a course of reading, the student will not be ill prepared for the history of his own country. Hume's History is a bad compilation. Hume is, moreover, the avowed enemy of the two principles which conduce most to the happiness of mankind, religion and liberty; and he who makes him the standard of his historical faith, will embrace numerous errors, arising not merely from design but from negligence. As a general history, Rapin's is preferable; and if the state papers be passed over, it will not be

found more voluminous than Hume. Perhaps a better course of English historical reading would be to take Dr. Henry's History for the early periods; from the conclusion of which he may proceed with Rapin to the date of Clarendon's History; and, for the affairs of Scotland, having recourse to the classical narrative of George Buchannan, and the elegant history of Queen Mary, by the accomplished Robertson. Clarendon's History, with his life, are invaluable records; but his statements will, in some instances, be corrected by Whitlock's Memorials, which every student of history ought to read, and by the plain and manly, but interesting Memoirs of the ill-treated Ludlow. Though Bishop Burnet's egotisms have been ridiculed by Pope, Arbuthnot and Swift, yet he will continue to be read by every one who wishes to inform himself correctly of the manners and circumstances of the times in which that excellent prelate and really candid writer lived. Mrs. Macaulay's history evidently favours republicanism, but her narrative is pure, and she is scrupulously exact in producing evidence and authority for all her facts.

The student of history should always read with a map of the country before him. A good

Biographical Dictionary is also an useful companion in the study of history. Various plans have been recommended for connecting history with chronology in the mind; the best method is perhaps to endeavour to fix in the memory the dates of some of the most remarkable events. The intermediate transactions will generally be found to have some link of association with the great events, and it will not be difficult to decide nearly on the date of any of them. There is, however, no better aid to the memory than Dr. Priestley's Historical Chart.*

On English History, the late Earl of Chatham thus wrote to his nephew. "If you have finished the abridgment of English History and of Burnet's History of the Reformation, I recommend to you next, before any other reading of history, Oldcastle's Remarks on the History of England, by Lord Bolingbroke. Let me apprise you of one thing before you read them, and that is, that the author has bent some passages to make them invidious parallels to the times he wrote in; therefore be aware of that, and depend, in general, on finding the truest constitutional doctrines; and that the

* Mon. Mag. May, 1797.

facts of history, though warped, are no where falsified. I also recommend Nathaniel Bacon's Historical and Political Observations; it is without exception, the best and most instructive book we have on matters of that kind. They are both to be read with attention, and twice over; Oldcastle s Remarks to be studied and almost got by heart, for the inimitable beauty of the style, as well as the matter. Bacon for the matter chiefly, the style being uncouth, but the expression forcible and striking.

"I desired you sometime since to read Clarendon's History of the Civil Wars. I have lately read a much honester and more instructive book, of the same period of history; it is the History of the Parliament, by Thomas May, Esq. If you have not read Burnet's History of his Own Times, I beg you will.

"I suppose you are going through the biographers, from Edward the Fourth downwards, nor intending to stop till you reach to the continuator of honest Rapin. There is a little book which I never mentioned, Welwood's Memoirs; I recommend it. Davis's Ireland must not on any account be omitted; it is a great performance, a masterly work, and contains much depth and extensive knowledge in state

matters, and settling of countries, in a very short compass. I have met with a scheme of chronology by Blair, showing all contemporary historical characters, through all ages: it is of great use to consult frequently, in order to fix periods, and throw collateral light upon any particular branch you are reading."*

Such is the recommendation of Chatham, a first rate authority.

Among the historical works produced in our own country, Bancroft's History of the United States, 3 vols. 8vo., is entertaining and carefully written; but it only brings the history down to a period shortly before the commencement of the Revolution. Frost's History of the United States, written for schools, brings it down to the year 1836. Prescott's Ferdinand and Isabella, and Irving's Columbus are delightful to read, and of the highest authority.

BIOGRAPHY.

Biography is a highly important branch of history. The biographer, by his accurate researches, supplies the deficiencies of the historian. What the latter gives us only in outlines

* Letters, passim.

and sketches, the former presents in more complete and highly finished portraits. Their province does not merely extend to those who have acted upon the great theatre of the world, as sovereigns, statesmen, and warriors; but to all who have improved human life by their useful discoveries, adorned it by their works of genius, and edified mankind by their examples. With what pleasure do we select a Bacon, a Boyle, a Newton, an Addison, a Locke, a Radcliffe, a Howard and a Hanway, from the multitudes which surround them, and become acquainted with their particular characters and conduct! To contemplate such men, not inflamed by vain ambition, or courting empty popularity, but seeking retirement, and giving dignity to the walks of private life by the efforts of genius, and the exertions of philanthropy, is a high gratification to the mind, and inspires it with an admiration and a love of those virtues, which come within the reach of general imitation.

No species of writing gives a more perfect insight into the minds of men, than their letters. We observe them as they thought in their retired moments, when, withdrawn from the bustle of the world, they gave free scope to

their unrestrained opinions, and poured them without reserve, into the bosom of their friends. Among the numerous instances, which might be selected of epistolary excellence, we distinguish the letters of Cicero, which display the sentiments of a vigorous mind, and give an insight into the eminent characters of his eventful times. Pliny, in letters remarkable for neatness and precision of thought, expresses the dictates of a cultivated and generous mind. If we turn our attention to the epistolary literature of our own country, we shall find that the piety and affection of Lady Russel, the quaintness and pleasantry of Howel, the manliness and political sagacity of Stafford, the philosophical exactness and cool judgment of Locke, the simplicity of Rundle, the moralizing vein of Johnson, and the taste and elegance of Gray, mark their respective letters with the strongest characters of originality, and give us the most pleasing pictures of their minds.*

Besides the names above enumerated by Mr. Kett, the following may be added, as justly celebrated letter writers, viz.: Pope, Swift, Ad dison, Steele, Arbuthnot, Gay, Shenstone, Sterne,

* Mr. Kett's Elements.

Lyttleton, Lady Mary Wortley Montague, Richardson, Chesterfield, Cowper, Sevigny, Maintenon, Burns, Lord Byron, and Horace Walpole.

Biography is, in general, a most pleasing as well as instructive branch of literature. When faithfully written it unveils man to man; discovers the virtues and vices, the nobleness and meanness of which he is capable; and shows how the original sameness of human nature is varied by the operation of external causes into ten thousand different shapes, and assumes as many shades and hues. Man, to be known, must be viewed in every situation; and whenever he is fairly exhibited, whatever may have been his rank, station, or circumstances of birth or fortune, a valuable addition is made to science. Whether the record respects the struggles of talents and worth through the chilling regions of obscurity and penury, up to the glittering eminences of fame and reward; or whether it details the operations of pride and ambition on minds born to wealth and power; it presents an useful lesson, which those who are disposed to exertion and virtue will not read in vain.*

* Mon. Rev.

I would begin the study of the human heart, says Rousseau, by reading the lives of particular men; for there the hero conceals not himself for a moment. The biographer pursues him into the most secret recesses, and exposes him to the piercing eye of the spectator; he is best known when he believes himself most concealed. I confess the genius of a people is very different from that of man considered as an individual, and that we shall be imperfectly acquainted with mankind if we neglect the study of the multitude; but it is also true, that we must begin by studying man in order to know mankind; and that if we know the propensities of each individual it will not be difficult to foresee their effects when combined in the body of the people. The lives of kings may be written and rewritten, but we shall never see another Suetonius. Plutarch's excellence consists chiefly in those very minutiæ into which we dare not enter. There is an inimitable gracefulness in his manner of painting great men engaged in trivial employments, and he is so happy in the choice of his incidents, that frequently a single word, a smile, a gesture, is sufficient to characterize his hero. Marshal Turenne was incontestably one of the

greatest men of the age in which he lived. The writer of his life has had the resolution to render it interesting by relating some minute particulars which make his hero known and beloved; but how many was he obliged to suppress, which would have taught us to know and love him still more! I shall instance one which I had from good authority, and which Plutarch would by no means have omitted, but which Ramsay, if he had known it, would not have dared to relate. The Marshal happened, one hot day, to be looking out at the window of his antichamber in a white waistcoat and night cap. A servant entering the room, was deceived by his dress, and mistook him for one of his under cooks. He crept softly behind him, and gave him a violent slap on the breech. The Marshal instantly turned about, and the fellow, frightened out of his senses, beheld the face of his master: down he fell on his knees. "Oh! my lord! I thought it was George!" "And suppose it had been George," replied the Marshal, rubbing his back, "you ought not to have struck quite so hard." There are few people capable of conceiving the effect which reading, thus directed, would have on young minds.

The "American Biography" of Mr. Sparks, in ten volumes, is a work of great merit. It forms a part of Harper's School Library, in which may be found many other biographical works of our own countrymen as well as of distinguished foreigners.

CHAPTER XIII.

THE MECHANIC'S STUDIES CONTINUED.

ACCOMPLISHMENTS IN GENERAL.

A PROPER degree of attention should always be paid to what are called the accomplishments of life, but they should never supersede for a moment more useful studies. Every occupation should be estimated according to its future utility, and as those points which are deemed essential to the demeanour of a gentleman should not be neglected, and demand but a small portion of time to acquire, a pupil should be early and properly attended by the best masters in the several departments of drawing, music, horsemanship, and dancing. These accomplishments, and the art of swimming, give a suppleness to the limbs, a grace of action, and an elegance of address and fine taste which always obtain the favourable prepossession of the company to whom a person may be introduced; but talents and virtues complete the conquest of affection, and convert the pass-

ing applause of the human race into a solid and durable esteem.

A copious selection, says Mr. Yorke, from the excellent letters of Lord Chesterfield to his son, are always before my pupil, which inspire him with a laudable desire of uniting to the character of a man of knowledge, the accomplishments of a gentleman. The object of instruction is to make men better, not to embrute them. Whatever, therefore, is deemed auxiliary to such a disposition, should be encouraged. No evil can arise from an easy address, or from agreeable manners. Politeness is the handmaid of civilization; perhaps it may be shown to be the attendant on virtue. Whatever means, therefore, are judged expedient to furnish the opportunity of exhibiting this amiable quality, are commendable, and ought to be adopted. I allude, in this instance, to genuine politeness, not to that false affectation of good manners, which consists in foppery and a servile imitation of the servile manners of the great, and of men of honour, as, by a strange perversion of language, they are improperly called. The term great man, is so equivocal, says Dr. Beattie, that I will have nothing to do with it. The vilest scoundrel on earth, if possessed of a

crown or a title, immediately commences great man, when he has with impunity perpetrated any extraordinary act of wickedness; murdered fifty thousand men, robbed all the houses in half a dozen provinces, or dexterously plundered his own country to defray the expense of a ruinous war, formed to satiate his avarice. The term honour is also of dubious import. According to the notions of the present times, a man may sell his country, murder his friend, pick the pocket of his fellow sharper, and employ his whole life in seducing others to vice and perdition, and yet be accounted a man of honour; provided he be accustomed to speak certain words, wear certain clothes, and haunt certain company. To the pernicious influence of this unnatural law of honour the just sentiments of Archdeacon Paley may be applied. "It is a law," says he, "which, being constituted by men occupied in the pursuit of pleasure, and for the mutual convenience of such men, will be found, as might be expected from the character and design of the law makers, to be, in most instances, favourable to the licentious indulgence of the natural passions. Thus, it allows of fornication, adultery, drunkenness, prodigality, duelling, and revenge in the ex-

treme; and lays no stress upon the virtues opposite to these."

If any additional supports were necessary in behalf of the argument that bodily accomplishments may be considered as a component part of the happiness and perfection of man, we might introduce the powerful authorities of Mr. Locke and Dr. Watts, who have applauded this mode of instruction, when limited to such views. The latter was a man of singular piety, modesty, and uprightness; the former was as much distinguished for the elegance of his manners, as for his knowledge of the world, and his deep insight into the powers of the human mind.

TASTE.

Taste is that power, which the mind possesses, of relishing the beauties found in the works of nature and art.

> Say what is Taste, but the internal powers,
> Active and strong, and feelingly alive
> To each fine impulse? a discerning sense,
> Of decent and sublime, with quick disgust
> From things deform'd.

It has been alleged that Taste is a natural talent as independent of art as strong eyes, or a deli

cate sense of smelling; and, without all doubt, the principal ingredient in the composition of taste is a natural sensibility, without which it cannot exist; but it differs from the senses in this particular, that they are finished by nature; whereas taste cannot be brought to perfection without proper cultivation: for taste pretends to judge not only of nature, but also of art; and that judgment is founded upon observation and comparison.

Though nature should have done her part, by implanting the seeds of taste, great pains must be taken, and great skill exerted, in raising them to a proper pitch of vegetation. The judicious tutor must gradually and tenderly unfold the mental faculties of the youth committed to his charge. He must cherish his delicate perception; store his mind with proper ideas; point out the different channels of observation; teach him to compare objects; to establish the limits of right and wrong, of truth and falsehood; to distinguish beauty from tinsel, and grace from affectation; in a word, to strengthen and improve by culture, experience, and instruction, those natural powers of sensibility and sagacity, which constitute the faculty

called taste, and enable the possessor to enjoy the delights of elegant learning.*

I do not call taste a species of judgment, although it be actually that part of judgment, whose objects are the sublime, beautiful and affecting; because this kind of judgment is not the result of reason and comparison, like a mathematical inference, but is perceived instantaneously, and obtruded on the mind, like sweet and bitter on the sense, from which analogy it has borrowed the name of taste.†

Taste presides with supreme authority over all the elegant arts. There are none so low in their subserviency to the uses of mankind, as not to afford subjects for its decisions. It extends its influence to dress, furniture, and equipage; but presides, as in its most distinguished and eminent provinces, over poetry, eloquence, painting, architecture, sculpture, and music; because among them genius takes its unbounded range, and exerts its fullest power. Taste is derived from the concurrent voices of men of various ages and nations, possessed of enlarged and cultivated understandings, who have surveyed the works of genius with close atten-

* Goldsmith. † Usher's Clio.

tion, and have recorded in animated descriptions the impressions made upon their minds. This authority has stamped its approbation upon works which have obtained the general applause of all ages and countries, and must still continue to produce a similar effect, so long as the intellectual powers of man remain the same; so long as his imagination and sensibility are capable of being affected by all which is beautiful, pathethic and sublime.

The advance of national taste is similar to the progress of taste from childhood to manhood. When the attention of an unpolished people is first directed to works of art, they are captivated by mere novelty; and the rudest paintings and most unpolished verses obtain their applause. In proportion as superior efforts of genius are made, the opinion of the judicious part of the public, at least, becomes more correct; and what at first delighted is finally rejected with disapprobation. As soon as comparisons are made between different productions of the same kind, true taste is brought into action, its decisions are called for, and the justness of its discriminations is universally acknowledged. The polished contemporaries of Horace blushed at the praises which their

ancestors had bestowed on the rude dialogues of Plautus, and were charmed with the polite and elegant comedies of Terence.

The lower orders of society are disqualified from deciding on the merits of the fine arts; and the department of taste is consequently confined to persons enlightened by education, and conversant with the world, whose views of nature, art, and mankind, are enlarged by an extensive range of observation, and elevated far above gross ignorance and vulgar prejudice.*

The general rudiments of taste are to be acquired first by reading books, which treat professedly on the subject. Secondly, by selecting and explaining beautiful passages in Shakspeare, Johnson, Sterne, &c. And lastly, by exhibiting and explaining prints of beautiful objects, or casts of the best antique gems and medalions. Authors have divided the objects of taste into the sublime, the beautiful, and the new; but another sect of inquirers into this subject have lately added the picturesque; which is supposed to differ from the beautiful by its want of smoothness, and from the sublime, from its want of size.†

* Mr. H. Kett.

† See Essay on the Picturesque, by U. Price, Esq.

Others have endeavoured to make a distinction between beauty and grace, and have esteemed them a kind of rivals for the possession of the human heart. By grace may be defined beauty in action; for a sleeping beauty cannot be called graceful, in whatever attitude she may recline; the muscles must be in action to produce a graceful attitude, and the limbs to produce a graceful motion.*

Taste, says Lord Kaimes, is one of our faculties which is the slowest in its progress towards maturity; and yet may receive some improvement during the course of domestic education. Compare with your pupils two poems on the same subject, or two passages. Take the lead in pointing out beauties and blemishes, in the simplest manner. After some time, let them take the lead under your correction. You cannot have a better book for that exercise than the Spectator. A pleasing vein of genteel humour runs through every one of Addison's papers, which like the sweet flavour of a hyacinth, constantly cheers, and never overpowers. Steele's papers, on the contrary, are little better than trash; there is scarcely a thought or sentiment which is worthy

* Dr. Darwin's Plan of Education.

to be transferred into a common-place book. My pupil reads a few papers daily without a single observation on my part. After some time, I remark to him the difference of composition, which, in the course of reading, becomes more and more apparent. The last step is to engage him in distinguishing the two authors. He at first made awkward attempts; from frequent trials, he began to distinguish. Now he will almost in the first period cry, "Foh! this is Steele, let us have no more of him."

If we wish to be directed to authors, who were eminent for correctness of taste, we may select in painting Fresnoy, Vasari, and Reynolds; in music, Burney; in eloquence, Cicero and Quintilian; and in poetry, Horace, Pope, Gray, and the Wartons. These were critics, who had the singular merit of teaching that art in which they were themselves distinguished; and their own works are an example and an illustration of their rules.*

It is no wonder that wholly uneducated people want elegance and taste. It is not from them that we are to seek the natural bias of the soul. The necessaries of life, when they are to be

* Mr. H. Kett's Elements.

procured by an individual for a wife and numerous young children are procured by vast labour and hardship. Labour requires strained, forced, and violent motions. This race of men walk not for pleasure, but to perform journeys of necessity. They take advantage therefore of bending the body forward, and assisting their motion by a sling with their arms. Their low station, their wants, and their drudgeries, give them a sordidness and ungenerosity of disposition, together with a coarseness and nakedness of expression; whence their motions and address are equally rude and ungraceful. This dishonoured state of man is the offspring of his wants, and of the miseries which yoke him down a slave to the globe which he tills, and depress together his mind and his body.*

DRAWING.

Drawing is not only an accomplishment the most elegant, agreeable, and ornamental, but, at the same time that it is the foundation of painting, is of the utmost utility to the sculptor, the civil and naval architect, the engraver, the engineer, the mathematician, and navigator. It

* Clio.

also assists the gardener, the cabinet maker, the weaver, &c. In short, there is scarcely a branch of civil society which is not indebted to it, from the maker of the iron rails before our house, to the tea urn on our table. To it we are indebted for representations of those elegant remains of antiquity which have contributed so much to the advancement of our knowledge of fine form. Volumes of verbal description will not convey so true an idea of an object, as the slightest outline. Hence the source of much of our knowledge in antiquity, of which language could convey no adequate idea. To be able on the spot to make a sketch of a fine building, beautiful prospect, or any curious production of nature or of art, is not only a very desirable and elegant accomplishment, but in the highest degree entertaining. To treasure up whatever may occur in our travels, either for future use or to illustrate conversation, to represent the deeds of former ages, to preserve the features of our most valued friends, has made this art not only one of the highest embellishments of our nature, but the delight of all ages. The greatest writers have united to praise, and empires to encourage it. It has been in the highest degree morally useful; and

where it has flourished, conferred honour on the country.*

It is impossible to judge accurately of the dimensions of bodies, unless we learn also to know their figures, and even to imitate those figures; for this imitation is founded on nothing else but the rules of perspective, and we cannot estimate the extension of bodies by their appearance, unless we have some knowledge of those rules. Children, being great imitators, all attempt to design; I will have my pupil, says Rousseau, cultivate that art; not so much for the art itself, as for the sake of giving him a good eye and a flexible hand. I will take care that he shall rarely imitate imitations. He should have before his eyes the original itself, and not the paper representing it. Thus he should design a house from a house, a tree from a tree, a man from a man, that he may be accustomed to observe minutely and accurately the appearance of bodies, and not take false and artificial imitations for those which are true and genuine. I would even discourage him from endeavouring to trace any thing from memory, till by frequent and repeated observations, its

* Mr. E. Dayes in Mr. Tilloch's Philosop. Mag. vol. xiv. 219.

figure should be strongly imprinted on his imagination; lest he should otherwise, by substituting some fantastic image instead of the real one, lose the knowledge of proportion, and a taste for the genuine beauties of nature.

If my pupil wishes to become a painter, he does not commence his career by a dry study of lines; he does not "imitate imitations;" he paints from nature. At the same time, that he may not lose the advantages derived from the labours of past ages, he submits his productions to a master of the art, who may correct his errors and accelerate his improvement. So in electricity, chemistry, &c., he begins by experiment, under the eye of a master, and thence either deduces his own general rules, or confirms those of others.*

MUSIC.

Music may be considered one of the most useful means which we possess of improving and cultivating the mind of man, and by far the most powerful in softening the heart, and rendering it susceptible of every fine and more exalted sentiment. Nor can music be called

* Northmore.

merely an art calculated to please and delight he senses alone, for certainly its execution employs the mind much more than the body. To instance the many surprising effects produced by music over the minds of men, even the most rude and barbarous, would be superfluous and impertinent. The delight which music imparts to the mind, can be enjoyed in every period of life, from the earliest infancy to the total decay of all vital powers. No art affording so much felicity and happiness can be so easily cultivated and attained. The influence of this part of education over the mind of the female sex, must be, and certainly is, highly beneficial. Their hearts are hence in a particular manner cultivated and refined, and those sensations are exercised and strengthened in their bosoms, which render them peculiarly lovely and amiable. Many females, however, are entirely deprived of the advantages resulting from this part of education.

It is sincerely to be lamented and regretted, that the truly respectable sect of Quakers should forbid the cultivation and practice of music in their societies; and it is wonderful that the effects which already have resulted from this prohibition, have not yet convinced them of the

impropriety and pernicious tendency of their unreasonable prejudice against music. Such indeed are the effects produced by the total neglect of this divine art among the society of Friends, that the tones of their voice in reading and public speaking are so harsh and discordant as scarcely to be endured by a person of a nice and delicate musical ear. The worship of the catholic church, and that of the quakers, are in this respect as opposite as possible. The catholics chant their worship, and its influence is thereby augmented.

The bravery and independence of the Swiss re universally known, and in no people, perhaps, is the influence of pathetic music so powerfully exerted. The inhabitants of many other mountainous countries afford striking examples of the same kind. No people are more possessed of true independence of mind than the inhabitants of the Highlands of Scotland, and in no country are the softer sensibilities of the heart more cultivated and indulged. I have never yet known an instance of a person capable of enjoying all the ecstacy of musical delight whose heart was not warm, tender and benevolent.*

* Dr. Cowan.

DANCING.

The design of this accomplishment is to obtain a graceful carriage, and a pleasing address on all occasions. It has been said, that "no person can either sit, stand, or walk well, unless he dances well." This is certainly carrying the matter too far. There are some who never so much as learned a step, who both sit, stand, and walk with more grace than some professed dancing masters. This art, however, frequently teaches young people to walk with firmness and ease, to enter a room gracefully, to incline the head or body, even when sitting and conversing, without any distortion; and removes that awkward stiffness, which in country people who have not had the advantages of a good education, is so apparent. To obtain great perfection in this art, though it be necessary for professional performers, would be a shameful waste of time, which might be infinitely better employed in mental attainments.

POLITENESS.

There is a fascinating manner in the address of some people, which almostly instantly conciliates the good-will, and even the confidence

of their acquaintance. Machiavel in his history of Castruccio Castricani observes, that his hero could assume such openness of countenance, that though he was known to be a man practised in every art of fraud and treachery, yet in a few minutes he gained the confidence of all whom he conversed with; they went away satisfied of his good will towards them, and were betrayed to their ruin. This enviable address, which may be used for good purposes as well as bad ones, is difficult to analyse; it may possibly consist simply in a countenance animated with pleasure at meeting and conversing with our acquaintance; and which diffuses cheerfulness by pleasurable contagion into the bosoms of others; and thus interests them in our behalf. It is not the smile of flattery, nor the smile of self-approbation, nor the smile of habit, nor of levity; but it is simply an expression of pleasure, which seems to arise at the sight of our acquaintance; and which persuades them, that they possess our love, for which they barter their own in return. However this conciliating manner may have been used, as above related, for bad purposes, it probably proceeded originally from friendliness and openness of heart, with cheerful benevo

lence; and that in those, who have in process of time become bad characters, the appearance of those virtues has remained, after the reality of them has vanished. What then is the method by which this enchantment of countenance can be taught? Certainly by instilling cheerfulness and benevolence into the minds of young people early in life, and at the same time an animation of countenance in expressing them; and though this pleasurable animation be at first only copied, it will in time have the appearance of being natural; and will contribute to produce, by association, the very cheerfulness and benevolence, which it at first only imitated. This is an observation to which those who have the care of young children should closely attend.

Next to the winning manners above described, the art of pleasing in conversation seems to consist in two things; one of them to *hear well*, and the other to *speak well*. The perpetual appearance of attention, and the varying expression of the countenance of the hearer to the sentiments or passion of the speaker, is a principal charm in conversation; to be well heard and accurately understood encourages our companions to proceed with pleasure, whatever may be the topics of their discourse.

To speak agreeably, in respect to manner, consists in a voice clear, yet not loud; soft, yet not plaintive; with distinct articulation, and with graceful attitudes rather than with graceful actions; as almost every kind of gesticulation is disagreeable. In respect to the matter, it should be such as coincides with the tastes or pursuits of those to whom the conversation is addressed. Hence it will appear that to hear well, and to speak well, requires an extensive knowledge of things, as well as of the tastes and pursuits of mankind; and must therefore ultimately be the effect of a good education in general, rather than a particular article of it. There are, however, faults to be avoided, and cautions to be observed, which should be pointed out to young people. Of these I shall mention,—1. That whenever the thirst of shining in conversation seizes on the heart, the vanity of the speaker becomes apparent; and we are disgusted with the manner, whatever may be the matter of the discourse. 2. That it is always childish, and generally ridiculous, when young people boast of their follies, or when they accuse themselves of virtues. 3. They should be apprised, that there is danger in speaking ill even of a bad person; both be-

cause they may have been misinformed, and because they should judge their neighbours with charity. A friend of mine was once asked how he could distinguish whether the lady, whom he meant to address, was good tempered, and gave this answer : "When any dubious accusation is brought in conversation against an absent person, if she always inclines to believe the worst side of the question, she is ill tempered." There are some nice distinctions on this subject of good nature in Lady Pennington's Advice to her Daughters, which are worth the attention of young ladies. 4 Strong asseverations, or a kind of petty oaths, such as "upon my honour;" appealing to others for the truth of an affirmation; are always wrong, because such strong expression derogate somewhat from the character of the speaker, as they intimate that a simple assertion may not be believed. 5. Loud laughter, or tittering in short shrieks, as practised by some ladies at cards, are reprehensible. Dignity of character always suffers by being violently agitated at trivial circumstances. 6. A uniform adherence to sincerity in conversation is of the first importance. No artificial polish of manners can compensate for the apparent want of

this virtue, nor any acquirements of knowledge for the reality of such a want. Opinions should be given with exact truth, if given at all; but when the characters of others are concerned, they should be delivered with diffidence and modesty. Lastly, a marked disapprobation should always be shown to indecency, immorality, or irreligion. In the softer sex, so great is their power in meliorating the characters of men, that if profligacy, infidelity, and debauchery, were universally despised, the morals of the age would be entirely reformed. To these might be added many other observations from various writers, concerning a due respect in conversation to superiors, good temper to equals, and condescension to inferiors; but as young people are not expected to speak with the wisdom, or precision of philosophers; and as the careless cheerfulness of their conversation, with simplicity of manner, and with grace, ease, and vivacity natural to youth, supplies it with its principal charms, these should be particularly encouraged, as there are few artificial accomplishments, which could compensate for the loss of them.*

* Dr. Darwin.

CHAPTER XIV.

THE MORALS OF THE MECHANIC.

The only lesson of morality proper for children, and the most important to persons of all ages, is never to do an injury to any one. Even the positive precept of doing good, if not made subordinate to this, is dangerous, false, and contradictory. Who is there who does no good? All the world, even the vicious man, does good to one or other party: he will make one person happy at the expense of making a hundred miserable; hence arise our calamities. The most sublime virtues are negative; they are also the most difficult to put in practice, because they are attended with no ostentation, and are even above that pleasure so flattering to the heart of man, that of sending away others satisfied with our benevolence. Oh how much good must that man necessarily do his fellow creatures, if such a man there be, who never did any of them harm! The injunction of doing no one harm, infers that of doing the least possible harm to the community in gene-

ral; for in a state of society the good of one man necessarily becomes the evil of another.*

I think it might be proved, that the best precepts of morality, inculcated even under the sanction of religious awe, are not of half the efficacy in the prevention of vice, as a taste for reading and science. Experience informs us how soon the principles of morality inculcated in childhood are forgotten, or accommodated to the prevailing customs of the world: but if a taste for science be acquired, the affections are then fixed upon a rational object; there is no temptation to allure them from the path of virtue; at least the most powerful of all incitements to criminal amusements is removed, the tediousness of life during the intervals of leisure.†

Plato has observed with great propriety, that the end of the education and instruction of youth as well as the end of government, is to make men better; and that whoever departs from this rule, however meritorious he may otherwise appear to be in reality, deserves neither the esteem nor the approbation of the public. The greatest erudition is of no value,

* Rousseau, b. 2. † Gregory's Essays.

if unattended with probity. It is worse, it is dangerous to the welfare and tranquillity of society Quintilian, in his admirable treatise, has laid it down as a rule in forming a perfect orator, that none but an upright man can merit that name, and therefore he asserts as a necessary qualification, that he should not only speak well, but also possess all the moral virtues. Mr. Justice Blackstone has wisely adopted a similar opinion in his introductory lecture on the study of the law, in which, after having enumerated all the qualities of the head, he adds to them those of the heart, as indispensably necessary to form a truly valuable English lawyer, a Hyde, a Hale, or a Talbot. And Dr. Blair has, with great elegance and propriety, suggested the same idea as a necessary ingredient in the character of a sublime writer. But this just sentiment is not to be restricted to any particular profession or order of men. The knowledge and practice of morality is the voice of nature, which is unbounded and universal: and however expedient it may be in those whose stations in life, render them objects of imitation or esteem, to perform with the most rigid punctuality every moral duty, it must not be forgotten, that the conviction of the utility of the practice,

should make it the common sense and common respect of all mankind.

The general rules of morality are formed by a constant observation of the fitness and propriety of actions in other men. What is fit to be done, and what excites universal applause, not only calls forth our own approbation, but warms us into a spirit of imitation. What ought to be avoided, we discover in the general sentiment of detestation which attends the perpetration of crime. The propriety of the former and the deformity of the latter quickly excite our emulation or abhorrence. We soon establish a general rule for the regulation of our conduct, which receives a full confirmation from the opinion of the rest of mankind. It is thus that the general rules of morality are formed. They are ultimately founded upon experience of what, in particular instances, our moral faculties, our natural sense of merit and propriety, approve or disapprove of. We do not originally approve or condemn particular actions; because, upon examination, they appear to be agreeable or inconsistent with a certain general rule. The general rule, on the contrary, is formed by finding from experience that all actions of a certain kind, or circumstanced in

a certain manner, are approved or disapproved of. An amiable action, a respectable action, a horrid action, are all of them actions which naturally excite for the person who performs them, the love, the respect, or the horror of the spectator. The general rules which determine what actions are, and what are not, the objects of each of those sentiments, can be formed no other way than by observing what actions actually and in fact excite them. The regard to those general rules of conduct, is what is properly called a sense of duty, a principle of the greatest consequence in human life, and the only principle by which the bulk of mankind are capable of directing their actions. Without this sacred regard to general rules, there is no man whose conduct can be so much depended upon. It is this which constitutes the most essential difference between a man of principle and honour, and a worthless fellow. The one adheres on all occasions, steadily and resolutely to his maxims, and preserves through the whole of his life, one even tenor of conduct. The other acts variously and accidentally, as humour inclination, or interest chances to be uppermost. On the most scrupulous observance of these rules of conduct, depends the very existence

and happiness of human society, which would crumble into nothing if mankind were not generally impressed with a reverence for them.

Among the many fortuitous events which spring up daily in the world, opportunities of inculcating a moral lesson frequently present themselves; and when the mind has habituated itself to inquiry and discrimination, it will insensibly acquire a considerable degree of acumen, which may hereafter be employed with great emolument. For as it developes its powers of reasoning, it will direct this habit to other purposes of life, and virtue will have so strengthened its seat in the understanding, that its principles will be both relished and admired when at a future period they are examined abstractedly. It is for this reason, we cannot too often, after having laid down a moral principle, proceed to explain it by a practical illustration. A very little industry will qualify any one for this undertaking. The same volubility of speech which is often admirably exerted to propagate the villanous reports of scandal, and to tear piecemeal the domestic happiness of others, may be diverted, by this means, to an honourable and useful end.

RELIGION.

Disbelief or distrust of the truth of Christianity arises in different men from different causes. Some who have been much accustomed to foreign travel, and have beheld opposite religions firmly established in different countries, on the contrary sides of the same mountain, or the neighbouring banks of the same river; and others who have learnt from the records of history that various systems of faith have successively prevailed in the same country; that they have been changed again and again within very short periods; and that each in its day has been implicitly received, and has produced, or, if an occasion offered, could have produced its martyrs; such persons are sometimes prone to form what they term the liberal conclusion, that all religions are alike. They assert that the Supreme Being has enabled mankind to discover, by the reasoning faculty with which he has endowed them, those plain precepts of morality, the observance of which is the only service required by him; and that the object of all religions, however they may be encumbered with fanatical rites and doctrines, which, in every country, the wise will inwardly regard

with contempt, is to inculcate the obligation of those precepts. Or they boldly pronounce that religion of every kind is superstition: in other words, that though certain modes of conduct ought to be followed, and others to be exploded, from principles of honour, and for the good of society; to deem men bound to act in any case with a reference to a supposed will of the Deity, if a Deity exists, is of all absurdities the grossest. Others again, who have addicted themselves to philosophical investigations, have become decided unbelievers. Not that philosophy is the enemy of religion. The former is the natural ally of the latter. An inquiry into the laws which God has prescribed to the human mind, to organized bodies, and to inanimate matter, leads at every step to a new display of his power, wisdom and goodness. But men who pursue it without any aim or desire to apply it to its most important use, that of heightening their reverence for the great Creator by a nearer acquaintance with his glorious attributes, easily become absorbed in the contemplation of second causes; and, though they may admit the existence, learn to deny the superintending care of the First Cause, and his interference with the course of the material or the

moral world. Others seek for refuge in unbelief, on the same principle on which many of the Jews did in the days of Christ; who "loved darkness rather than light, because their deeds were evil, and would not come to the light lest their deeds should be reproved." Resolved to persist in the vicious practices which Christianity proscribes, they take pains to convince themselves that the gospel is the production of fraud and delusion; they catch eagerly at every objection against it of every kind, and turn from whatever seems to make in its favour; in the language of scripture, they wink purposely with their eyes lest they should see, and shut their ears lest they should hear, and harden their hearts lest they should believe. Others by degrees becoming altogether immersed in political, commercial, or professional business, or in a continued succession of dissipated amusements, proceed from the omission of the practices of religious duties to the disuse and disregard of religious considerations, and ultimately to the disbelief of revealed religion, if not of all religion. And lastly, disdain of thinking with the vulgar, disgust at casual instances of superstition, and difficulties as to particular

doctrines, occasionally contribute to lead men to unbelief.

Besides the confirmed unbelievers of each of these descriptions, there are many persons who, from various causes, advance only part of the way on the road to infidelity, and stop short at different stages of doubt and distrust.

Concerning unbelievers and doubters of every class, one observation may almost universally be made with truth; that they are little acquainted with the nature of the Christian religion, and still less with the evidence by which its truth is supported.

Now those who question or deny the truth of Christianity will yet readily admit, that *if* the Supreme Being has actually made a revealed communication of his will, and has unequivocally addressed it to all mankind; and *if* there are facts connected with that revelation which are acknowledged even by its enemies, and which justly afford, independently of other evidence, a strong presumption of its reality; those persons must be highly guilty, who, having sufficient abilities and opportunities for inquiry, refuse or neglect to examine into the validity of its pretensions; and to examine with fairness, and with the attention which the subject demands.

Is it then a thing highly improbable in itself that the Creator of the world should have given a revelation to mankind, and at the period when Christianity first appeared? If the present stage of existence is but a very small part of the whole duration of a human being; if this stage is designed for the purpose of trial and probation, and is thus to fix the state of each individual for ever; if men were in fact ignorant of the certainty of these momentous truths, and unable to ascertain it by unassisted reason; if, for want of a knowledge of that certainty, they were become a prey to crimes and delusions, indulging themselves in every species of wickedness, and worshipping stocks and stones, and *personified vices*, with absurd and abominable rites; can it be improbable that He who had manifested his goodness in creating them, should add another proof of the same disposition by imparting to them the further light necessary to correct their wanderings, and to guide them steadily in the way to happiness?

They who are led by these or other considerations to regard a revelation as a thing not improbable in itself, ought from that circumstance to feel, and naturally will feel, a greater readiness to inquire into the evidence of any

professed revelation which bears outward marks of reality. They who deem the existence of a revelation highly improbable cannot affirm that it is impossible; and ought consequently in a similar case to institute a similar inquiry. For an antecedent persuasion of the improbability of the Deity's acting in any particular manner is no more a reason for refusing to examine whether he has not acted thus, if existing facts afford strong presumptive evidence that he has, than it would be for refusing to believe that he has, if conclusive evidence were produced.

The question then which remains to be answered is this. Are there any leading circumstances attending Christianity, circumstances generally admitted, and resting on independent proofs, which seem scarcely capable of being accounted for on any supposition but on that of truth; and consequently furnish so strong a presumption of its being a divine revelation as to render those who doubt, or deny it, not merely imprudent but criminal, if they do not seriously inquire into its evidence?

The following statement, I apprehend, will justify the answering of that question decidedly in the affirmative.

The Christian religion, whether true or false,

had its origin in a country and nation held in proverbial contempt in almost every part of the known world. The author of the religion was not only a Jew, but of the lowest rank among the Jews. He is universally allowed to have been uninstructed in literature and philosophy. He employed, in propagating his doctrine, assistants who were also Jews, and of a station as obscure, and of minds as little cultivated by learning, as his own. The religion which they preached was of such a nature as to be generally and unavoidably most obnoxious. It was avowedly intended to supersede and annihilate every other religion. It attacked not only the doctrines and ordinances of the Jews, which they regarded as having been appointed by God himself; but those inveterate prepossessions which were rooted no less firmly in their hearts; pronouncing the abolition of the peculiar privileges of the Jewish race, and the free admission of the abhorred Samaritans and Gentiles to all the benefits of the new dispensation. It not only exasperated the Romans by branding as impious and detestable those rites and institutions which they had received with implicit reverence from their remote ancestors; and deriding as vain fictions every object of

their adoration, even all the tutelary deities of their empire; but it also touched their jealousy in the tenderest point, by suggesting a prospect of the revolt of Judea, and holding forth to their imaginations a competitor of Cæsar, and the portentous appearance of the long expected sovereign, whom fate had destined to arise in the east. The founder of Christianity had neither the favourable circumstances to turn to his advantage, of which other teachers of new religions have availed themselves; nor did he resort to those methods of proceeding to which they owed their success. He did not, like Mahomet, pay court to a particular set of men, or a particular sect; nor, like him, artfully conciliate persons of all the different religious persuasions in the country, by adopting and incorporating into his own system some of the principal of their respective tenets; nor, like him, permit licentious indulgences and promise licentious rewards to his followers; nor, like him, direct the propagation of his doctrine by the sword. He did not confine his instructions to solitudes and obscure hamlets; but delivered them in the most public manner, in populous cities, in the most frequented parts of Jerusalem itself. He did not rest his pretensions on any

species of evidence of a secret nature, or in any respect not generally cognizable by his cotemporaries; but appealed to professed miracles performed in the sight of multitudes, and of such a kind that every man could judge as to their reality. He was not permitted by the contempt or the supineness of his enemies to proceed unmolested in making proselytes; but was actively opposed from the beginning by the priests and chief men of the national religion; was repeatedly in danger of losing his life; and after a short ministry of three years duration at the utmost, was delivered to the civil power, and crucified as a malefactor. Yet notwithstanding this event the progress of the religion continued. The disciples of Christ, though they could have no reason to expect better treatment than their master had received; though they expected, as they had been taught by him and professed to expect, nothing in the present life but troubles and persecutions, persevered in preaching the same religion as he had taught, with this additional and extraordinary circumstance that their master, on the third day after his crucifixion, had arisen from the dead: and encountered the severest punishments, and death itself, rather than cease from

publishing and attesting doctrines and facts, which, if false, they could not but know to be so; and from the preaching of which, if true, they could look for no present advantage. And from these humble beginnings, and by these unpromising methods, did Christianity make its way so successfully, that within three centuries from the first preaching of Christ, it penetrated to the remotest extremities of the Roman empire, and established itself on the ruins of every other religion which it found existing.

When all these circumstances are considered, and they are such as unbelievers in general are ready to admit, it seems nearly impossible not to come to the following conclusion:—that a religion of such an origin, and avowedly aiming at such objects; a religion thus destitute of all worldly means of credit and support, thus provoking and experiencing every kind of worldly opposition, could scarcely ever have obtained belief and acceptation, if its pretensions had not been founded on irresistible truth; and consequently, that its establishment under all these circumstances affords so very strong a presumption that it is true, as necessarily to render every competent judge to whom they are known, and who doubts or disbelieves Christianity, crimi-

nal in the sight of God, if he does not carefully examine into the specific evidence by which that religion is supported.

This is the conclusion to which it has been my object to lead by fair reasoning the candid reader, who distrusts or denies the truth of the Christian revelation. If this conclusion appears to him well established, he will naturally seek for a detailed account of the evidence of the Christian religion in treatises written professedly on the subject; and will make himself acquainted with the many striking internal proofs which it bears of its own authenticity, by a diligent and attentive study of the Scriptures. And let him conduct the whole of his investigations with that impartial spirit which is always essential to the discovery of the truth, whatever be the subject under discussion; guarding against the influence of former prepossessions, and former practices, with a degree of caution and solicitude proportioned to the supreme importance of the inquiry in which he is engaged. Let him be prepared "to do the will of God;" and he will not fail, "to know concerning the doctrine whether it be of God."

I would in the next place offer a few observations to the consideration of those believers

in Christianity, who contend that an exact observance of all its precepts is more than is now required of them.

This plea for deliberate deviations from the strictness of obedience, a plea which we more frequently hear obscurely intimated than explicitly stated, appears, when unfolded, to resolve itself into the following assertions :—that if the generality of men would act in scrupulous conformity to the precepts of Christianity, no individual could be vindicated were he to conduct himself otherwise; but that every man must take the world as it is, and consider what is practicable in the existing state of things : that if government, for example, cannot be carried on without a certain degree of deceit and corruption, the politician is excusable who practises it; that if men in trade cannot maintain their station without using the same objectionable arts which are adopted by their competitors, the necessity of the case is a sufficient apology; that similar reasoning is applicable to every other profession; that extravagant and needless latitude would certainly be unjustifiable; but that it is absurd to require points of morality to be pushed to extremes, and to refuse

to make necessary allowances for compliance with established customs.

Before we examine what countenance the plea in question meets with in the Scriptures, it may be useful to inquire whether it approves itself to sober reason.

Now, since they who allege this plea, professedly make the degree in which it is customary for men to deviate from the rules prescribed in the Gospel, the standard measure of the degree of latitude in deviating from them which each individual is at liberty to use; they must unavoidably admit, if they will reason consistently with their own principles, that when the general depravity is augmented in any proportion, exactly in the same proportion is that latitude augmented; and consequently that a degree of latitude, which in one state of things they pronounce extravagant and unnecessary, may become highly needful and proper in another. This in fact is to affirm, that instead of the practice of men being rendered conformable to the laws of God, the degree of obedience due from any man to those laws depends solely on the practice of his neighbours; and that if it should be the general practice utterly to disregard and contemn them, no individual

would be under any obligations to pay to them the slightest attention whatever. If an argument like this, which strikes directly at the root of all religion, cannot be maintained by those who believe in Christianity; neither can the plea which necessarily involves it.

In the next place, does this plea receive more encouragement from the Scriptures? From that quarter it experiences nothing but repulse and condemnation. Those who urge it cannot produce one single text authorizing an individual to relax in his obedience to the precepts of the Gospel, for the sake of escaping difficulties and losses, through fear of giving offence, through deference to custom or authority, or through any worldly motive whatever. What is the language of the Old and New Testaments on the subject? "Thou shalt not follow a multitude to do evil."—"Be not conformed to this world," (that is, to the evil principles and practises which prevail in it,) "but be transformed by the renewing of your mind, that ye may prove what is that good, and acceptable and *perfect* will of God."—"Love not the world, neither the things that are in the world. If any man love the world, the love of the Father is not in him For all that is in the world, the

lust of the flesh, and the lust of the eyes, and the pride of life, is not of the Father, but is of the world. And the world passeth away, and the lust thereof: but he that doeth the will of God abideth for ever."—"Be ye therefore *perfect*, even as your Father which is in Heaven is perfect."—"The love of Christ constraineth us, because we thus judge, that if one died for all, then were all dead: and that he died for all, that they which live *should henceforth not live unto themselves, but unto him which died for them and rose again.*"—"What shall it profit a man, if he shall gain the whole world, and lose his own soul? Or what shall a man give in exchange for his soul? Whosoever therefore shall be ashamed of me, and of my words, in this adulterous and sinful generation, of him also shall the Son of man be ashamed, when he cometh in the glory of his Father with the holy angels." To these passages are to be added the directions incidently given by St. Paul to persons in many different stations, exhorting them to fulfil the respective offices peculiar to those stations "for conscience sake, as unto the Lord, and not unto men;" directions which, by parity of reasoning we may rest assured that the apostle would have applied to all other

situations and circumstances of life, if he had been led by his subject to notice them distinctly And he did in fact make the application universal, when he delivered these general and comprehensive precepts: "Whatsoever ye do, do all to the glory of God."—"Whatever ye do, in word or in deed, do all in the name of the Lord Jesus." A serious desire to please God in all we do, rendering the manner of pursuing the business of our calling, be it what it may, one of the expressions of that desire, is the grand principle which these passages inculcate; and it is the principle which, beyond all others, I could wish to impress on the mind of the reader, whatever be his station or profession, as being the only one which will lead him steadily to fix his attention on the duties which he has to perform, and the temptations which he must encounter. It is impossible to conceive that he who knowingly deviates from the path of moral rectitude and Christian duty, because most others in the same rank and profession with himself deviate from it, and because, by forbearing to deviate, he should incur embarrassment and losses, odium and disgrace, is, in that instance, acting consistently with the letter or the spirit of the various scriptural injunctions which

have been quoted. Let those who find themselves tempted to such deviations, consider whether it is not probable that the Supreme Being, on whose providence the success of every undertaking depends, will prosper those who scrupulously observe the laws which he has prescribed for their conduct, and leave the issue in his hands, rather than those who manifest their distrust of his care by resorting to arts and practices which he has forbidden; whether those who are injured in their worldly prospects by their conscientious adherence to the line of rectitude, are not entitled to the full benefit of the scriptural consolation, "If ye suffer for righteousness sake, happy are ye:" and whether it is not the part of wisdom as well as of duty, whatever be the event at present, to regulate every action by that rule, according to which it will be judged at the last day